# HAND BOOK
OF
# HOUSE SANITATION

*For the use of all Persons Seeking a Healthy Home*

EARDLEY BAILEY-DENTON.
C.E.

# A HAND BOOK

OF



# HOUSE SANITATION:

FOR THE USE OF ALL PERSONS SEEKING

# A HEALTHY HOME.

A REPRINT OF THOSE PORTIONS OF MR. BAILEY-DENTON'S LECTURES ON SANITARY ENGINEERING GIVEN BEFORE THE SCHOOL OF MILITARY ENGINEERING, CHATHAM, WHICH RELATED TO THE "DWELLING."

*ENLARGED AND REVISED BY HIS SON;*

EARDLEY F. BAILEY-DENTON, C.E., B.A. OXON.

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London:
E. & F. N. SPON, 16, CHARING CROSS.
New York:
446, BROOME STREET.

1882.

HARRISON AND SONS,
PRINTERS IN ORDINARY TO HER MAJESTY,
ST. MARTIN'S LANE.

# PREFACE.

THIS Treatise on House Sanitation is published for the following reasons :—

In 1876 a series of Lectures, embracing the treatment of the Dwelling, was delivered by Mr. Bailey-Denton before the School of Military Engineering at Chatham, and published under the title of "Sanitary Engineering;" and that work having met with a ready sale its publication is now exhausted.

Since the delivery of those Lectures a more general interest in Sanitation than then existed has grown up, and the desire to occupy houses of a healthful character being strongly manifested, has called forth many advisers and a multitude of devices to meet that desire. Under these circumstances the Editor, with Mr. Bailey-Denton's consent, has determined to issue, in a much cheaper form than the Lectures referred to, a Revised Edition of such portions as treated of "The Dwelling," and its Sanitary requirements.

There has long been felt the want of a Hand Book which—freed as much as possible from trade technicalities—should be so comprehensive in its character as to enable the house-owner and the house-holder, as well as the architect and builder, to understand and appreciate the arrangements and appliances which will best secure that healthy condition which is daily becoming more

and more a *sine quâ non* in dwellings of all descriptions, the recognition of which has, in fact, called into existence the "sanitary engineer" of the present day. It is with a view of supplying this want that the Editor has undertaken not only to reprint from the original text of "Sanitary Engineering," 1877, those portions bearing on "The Dwelling," but to describe and pourtray in a classified manner those arrangements and appliances or devices which have been brought before the public since those Lectures were given. He begs that it may be borne in mind that in the following pages the term "Dwelling" means every structure occupied by human beings, whether it be a palace, mansion, cottage, factory, or shop, and that in each the same obligations for the preservation of health exist.

"The Dwelling" forms the *unit* of Towns and Villages, and in that character and position it suffers not only the drawbacks necessarily attending all habitations in which human beings are collected, but the evils arising from combined sewerage, made obligatory by the Public Health Acts. By the construction of common sewers, a means of conveying infection and gases from one part of a district to another has been afforded, and individual injury has followed a general benefit. To *disconnect* the Dwelling from the common sewer in a manner to secure an outlet for its liquid refuse, while excluding the emanations from the sewer, is a matter of necessity.

To render this treatise as practically useful as possible, its contents have been divided into two parts, entitled "AIR" and "WATER." To the pure or impure condition of these essential elements of life is to be traced the freedom from or the existence of those zymotic or ferment diseases which, Hygienic Statistics show, constitute more than half the ailments to which humanity is subject.

It is only within very recent years that we have realized the fact that in the most costly houses of the Metropolis and other

large cities, where vast sums of money have been spent in decorating and beautifying them and in securing comfort and luxury to their occupiers, and that in the spacious mansions of our rural districts, where nature herself contributes so much to health, the very first conditions essential to pure air and pure water have in the majority of instances been neglected. In many of these high-class dwellings, in fact, the domestics exist in ill-ventilated basements and attics, in which the "air" is often as corrupt as air can well be, whilst all the inmates alike—principals and domestics —consume "water" obtained from wells or tanks, and cisterns, which impart to it injurious qualities.

If this is the condition of the dwellings of the higher and wealthy classes, the sanitary state of the houses of the middle and lower classes, though in many respects not worse, is certainly not better. If examined, they would be found faulty in some particulars, though the evils which really exist are often greatly exaggerated. With house-holders whose incomes govern the rent they pay for their dwellings,—which is necessarily greatly the case with the middle and lower classes,—little or no thought is given to sanitary arrangements, nor is any examination into their sanitary condition ever made. In a majority of instances where defects would be discovered on examination, a very small outlay would suffice to effect the necessary rectification, whilst the outlay would be speedily recovered in the saving of medical advice.

Fortunately for the people of this country the advance recently made in sanitary science has led to the recognition of the value—the necessity—of a periodical examination of all dwellings by properly qualified persons, and this will inevitably lead to the compulsory rectification of evils, the removal of which, unfortunately, now remains optional.

In designating the present treatise a "Hand Book," the Editor is perfectly cognizant of the fact that the term is too wide to be correctly applied to it. To treat of *all* points bearing upon

healthy homes, a *hand book* should not only include the duties of the sanitary engineer, the architect, and the builder, but it should deal with medical and legal considerations, extremely interesting to both landlord and tenant, but which would extend the work far beyond the limits now contemplated. They are, therefore, omitted.

An important object to remember in sanitation is the aptitude of all persons to run to extremes of prevention and remedy, whenever their minds are aroused to personal danger. It is hardly necessary to say that such extremes should be avoided, for all expenditure not absolutely necessary must, sooner or later, have a deterring effect, and operate disadvantageously to a science recognised as one of the most important of the day.

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## PART II.—WATER.

# AIR.

## BOOK I.

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AIR CHEMICALLY AND PHYSICALLY CONSIDERED



## CHAPTER I.

I. Air in Relation to the Dwelling.—It is well understood by sanitarians that in order to secure the best hygienic conditions in every dwelling, the primary object to be aimed at is to distribute throughout both the living and sleeping apartments the purest air obtainable from without, and by the best known internal arrangements to counteract, as far as is possible, (1) the vitiation of air caused by, and inseparable from, the respiration of its inmates; (2) the existence of corrupt organic matter consequent on most of the diseases which befall humanity; (3) the dissemination of the products of imperfect combustion of materials used for lighting and warming; (4) the dispersion of the solid particles and offensive gases evolved from trade processes, and in the preparation of food; and (5) the decay and putrefaction of both vegetable and animal matter of which that food consists.

Upon the careful admission and circulation of fresh air to correct the impurities generated in the dwelling,—if the arrangements be associated with an ample supply of unexceptionable water,—will depend its character as a healthy home, for it will only be by the maintenance of pure air and pure water that the old, the young and the weak will be relieved of many of those maladies to which they are specially sensitive.

As the benefits of house sanitation become more fully recognised, the renting value of dwellings will necessarily depend upon the arrangements made to secure a healthy condition. Thus it will become a matter of increasing importance to architects, surveyors, and builders, when designing and constructing dwellings, and in a greater degree to owners and lessees, who have to let them, that they should possess such appliances as will render them acceptable to tenants, who will become more and more alive every day to what their landords are bound to supply.

II. Constituents of Normal Air.—Air in its normal condition consists of about four-fifths by volume of nitrogen and one-fifth of oxygen mixed with a very small proportion of carbonic acid.* Speaking more precisely, it has been ascertained by the valuable researches of Dr. Angus Smith, that very pure air contains not less than 20·99 per cent. of oxygen, and not more than ·03 of carbonic acid.

[Weight of Air.

| | | |
|---|---|---|
| 100 cubic inches weigh (Prout) .. ... ... | 31·117 | grains. |
| (Bist and Arago) ... | 31·074 | ,, |
| (Dumas and Bousingault) | 31·086 | ,, |
| (Regnault) ... ... | 33·935 | ,, |
| Mean of four observations... | 31·053 | ,, |

Taking the mean of these experiments, 1 cubic foot weighs 536·6 grains. Air is therefore 14·45 heavier than hydrogen, and 816 times lighter than water.

The *average pressure* of the air on the surface of the earth and at the level of the ocean is equal to 15 lbs. on the square inch, that is, the air is capable of supporting a column of mercury of 30 inches, or a column of water of 34 feet.—*Meymott Tidy.*]

III. Of Foreign Polluting Matters.—Excluding from consideration the watery vapour that exists to the extent of 40 per

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* Nitrogen is a gas devoid of either colour, taste, or smell. It acts chiefly in diluting the oxygen. In pure nitrogen animals cease to live. Its weight is a thirty-sixth part less than common air.

Oxygen is without either taste or smell. Of all elements it is most abundant, forming eight-ninths by weight of the water, one-fifth by volume of the air, and one-third of the solid matter of the globe. Though absolutely necessary to the life of man and animals it is too strong to be breathed for any length of time in a pure condition without fatal results. Oxygen is one-ninth part heavier than common air.

Carbonic acid is a gas which, unlike oxygen and hydrogen, possesses a perceptibly sour taste. It is described as a compound of carbon and oxygen, and is the result of the combustion of carbon. It was called "fixed air" by our older chemists, and to coal-miners and well-sinkers it is known as "choke damp." For plants it is essential, being the source from which the carbon of their tissues is derived.

cent. of saturation in the driest, to complete saturation in the dampest air, and which may therefore be considered, though varying in quantity, to be almost a normal constituent, the foreign matters to which I have before referred, and which impart to the air those impurities which vitiate its normal condition, are—(1) the gases which rise in the shape of ammonia from organic matters, as decay and putrefaction take place; (2) those acids or gases which emanate from inorganic matters in their natural state, or when brought into use by man; and (3) mechanically suspended impurities, *i.e.*, those substances consisting of particles of the soil or dust, the pollen and seeds of plants, decaying tissue, &c., which float in the air, are of minute size, and may be partially seen by the eye in any ray of light. It is these suspended and floating particles that have been shown by Professor Tyndall to reflect and scatter light itself.

The amount of watery vapour which in this country is considered most congenial to health, is from 65 to 75 per cent. of saturation. [More than this checks evaporation from the body, while less causes too great evaporation, parching the mouth and drying the skin. It has been noted that in certain places, remarkable as health resorts, the degree of saturation is singularly uniform.—*Meymott Tidy.*]

IV. Of Counteracting Agencies.—These deteriorating foreign materials, however, are counterbalanced by natural agencies, winds and currents, diffusion, oxidation, and the very powerful influences of vegetation. Beyond these, there is the action of that substance known as *ozone.* This valuable element is described by Dr. de Chaumont as a modification of oxygen with which more than the usual number of atoms are brought together. "Ozone," he says "oxidizes (burns, in fact) organic matter in great rapidity, much more rapidly, in fact, than ordinary oxygen. In this way it may be considered the great scavenger of the air." Dr. Cornelius Fox describes the sources of ozone to be "the oxidation of metals, the decomposition of rocks, the germination of seeds, the growth of plants, the falling of dew, rain, hail, and snow, the collison between air currents of different degrees of humidity proceeding from opposite quarters with one another, or with the the earth; the evaporation which is continually proceeding from saline fluids, such as oceans, seas, and lakes; the dashing and splashing, the smashing and crashing of the restless waves on the rocky coast;" which, he says, "are all concerned in the simultaneous development of electricity and ozone." This description expresses not only the sources of ozone, but includes, in fact, the several agencies which counteract air pollution.

[More ozone is found at high than at low levels.—*Meymott Tidy.*]

V. Attainable Standard of Air.—According to Dr. Angus Smith a favourable, though not the purest specimen of air, may be taken to contain by weight of oxygen 20·96, of nitrogen 79·00, and of carbonic acid ·04 per cent., with a varying quantity of watery vapour.

We may take these figures as representing a fair attainable standard of pure air, and may therefore conclude that directly these proportions are altered by an increase of carbonic acid and a mixture of other foreign matters involving a reduction of oxygen the quality of the air is lowered.

[Air in fact "with a very small loss of oxygen is perceptibly deteriorated, if the place of the oxygen is occupied with carbonic acid and exhalations from the person, although we are not able to say how far this is the case when carbonic acid alone is substituted for this small amount of oxygen."—*Angus Smith.*]

The diminution of oxygen is, however, very sensibly felt directly its quantity is reduced as low as 20·75 per cent.

VI. Quantity of Air Respired by Human Beings.—To understand to what extent the loss of oxygen, and an excess of carbonic acid mixed with deleterious foreign substances may effect the health of human beings, it should be understood that Professor Huxley states that in respiration about 350 cubic feet of air pass through the lungs of each individual per diem. "In passing through the lungs the air would lose from 4 to 6 per cent. of oxygen, and gain 4 to 5 per cent. of carbonic acid.

"During 24 hours there would be consumed about 10,000 grains oxygen, and produced about 12,000 grains carbonic acid corresponding to 3,300 grains of carbon. During the same time about 5,000 grains or 9 ozs. of water would be exhaled by the lungs.

"In 24 hours such a body would vitiate 1,750 cubic feet of pure air, to the extent of 1 per cent. or 17,500 cubic feet of pure air to the extent of 1 per 1,000. Taking the amount of carbonic acid in the atmosphere at three parts, and in expired 470 parts in 10,000, such a body would require a supply per diem of more than 23,000 cubic feet of ordinary air, in order that the surrounding atmosphere might not contain more than 1 per 1,000 of carbonic acid (when air is vitiated from animal sources with carbonic acid to more than 1 per 1,000 the concomitant impurities become appreciable to the nose). A man of the weight mentioned (11 stone), ought therefore to have at least 800 cubic feet of well ventilated space."

Upon this subject Dr. de Chaumont says that each adult consumes in food from 3,500 to 4,000 grains of carbon in 24 hours, *i.e.*, from 8 to 9 ozs., and he exhales as carbonic acid about the same quantity, which is equal to 17 cubic feet of the gas to

vitiate the atmosphere. In addition to this gas, a quantity of watery vapour is given off from the person varying according to circumstances from 6 to 27 ozs.; and Dr. de Chaumont adds, "an assemblage of 2,000 persons will give off in two hours (in vapour) 17 gallons of water, and nearly as much carbon as would be extracted from a cwt. of coals."

Dr. Parkes says in his "Practical Hygiene" that "an adult man in ordinary work gives off in 24 hours from 12 to 16 cubic feet of carbonic acid gas, and also emits an undetermined quantity of carbonic acid gas by the skin."

VII. Of Oxygen.—["The mean quantity of oxygen in the extremely pure air at the sea shore, and on the heaths of Scotland, is represented to be 20·999 per cent., while the mean of the low marshy places (Scotland) is 20·922."—*Angus Smith*]. From these figures it will be seen that the better air of the sea shore and the heaths contain ·039 per cent. of oxygen above that expressed in the standard of purity which I have quoted, while the worse air of the marshes contain ·038 per cent. below it. It will be observed, however, that although the sanitary conditions of the two are very different, that difference is limited to ·077 of one part in 100 parts, or, in other words, to rather less that 7¾ parts in 10,000 parts.

To show how the loss of a small portion of oxygen indicates a very great reduction of salubrity, the quantities of oxygen collected from various authorities, which have been found to exist in different places under different conditions are appended :—

Oxygen.—Standard 20·96 Per Cent.

| | Oxygen, per cent. | More or less than attainable Standard, per cent. |
|---|---|---|
| Front of Glasgow Exchange... ... | 20·895 | ·065 less. |
| Kirk Street, Glasgow... ... ... | 20·875 | ·085 ,, |
| Regent Street, London, November... | 20·865 | ·095 ,, |
| Hackney ... ... ... ... | 20·835 | ·125 ,, |
| Chelsea... ... ... ... ... | 20·810 | ·150 ,, |
| Middle of Hyde Park... ... ... | 21·005 | ·045 more. |
| Metropolitan Railway, Underground | 20·600 | ·360 less. |
| Sitting Room ... ... ... ... | 20·890 | ·070 ,, |
| Small Room, petroleum lamp burning | 20·840 | ·120 ,, |
| Pit of Theatre.. ... ... ... | 20·740 | ·220 ,, |
| Gallery of Theatre ... ... ... | 20·620 | ·330 ,, |

VIII. Of Carbonic Acid.—An increase of a very minute proportion of carbonic acid in the air, with a corresponding loss of oxygen, is quickly perceptible to the senses, although the difference (if accurately ascertained by analysis) will be indicated by figures in the second or even third place of decimals.

["Some people will probably inquire why we should give so much attention to such minute quantities—between 20·980 and 20·999—thinking these small differences can in no way affect us. A little more or less oxygen might not effect us : but supposing its place occupied by hurtful matter, we must not look on the amount as too small. Subtracting 0·980 from 0·999, we have a difference of 190 in a million. In a gallon of water there are 70,000 grains; let us put into it an impurity at the rate of 190 in 1,000,000, it amounts to 13·3 grains in a gallon, or 0·19 grammes in a litre. This amount would be considered enormous if it consisted of putrifying matter, or any organic matter usually found in waters ; but we drink only a comparatively small quantity of water, and the whole 13 grains would not be swallowed in a day, whereas we take into our lungs from 1,000 to 2,000 gallons of air daily. The detection of impurities in the air is therefore of the utmost importance, and it is only by the finest methods that they can be ascertained in small quantities of air, even when present in such quantity as to prove deleterious to health."—*Angus Smith.*]

It is needless to point out that the amount of carbonic acid associated with contaminating foreign matters will necessarily be found to increase, and the amount of oxygen to decrease in a greater degree in "confined spaces" than in the open country. I am not at this moment treating of the air of rooms within dwellings, with which the architect has more to do than the engineer, but of the outside atmosphere upon which the inmates of all dwellings depend as a source from which to dilute the inner air when it has become polluted by the respiration and combustion constantly going on in all human habitations, mills, factories, &c., and in the stables, outbuildings, &c., occupied by domestic animals. With this outside atmosphere the engineer has everything to do.

That we may, however, appreciate the differences between the attainable standard of pure air, which I have quoted, and the fairly good atmosphere of open spaces, and compare both with the air of confined inner spaces, I will give the quantity of carbonic acid as it is found to exist in the air of a variety of places.

CARBONIC ACID.—STANDARD ·04 PER CENT.

OPEN SPACES (*Manchester*).

| | Per cent. | More or less than standard, per cent. |
|---|---|---|
| Fields in Green Leys ... ... ... | ·0383 | ·0017 less. |
| Old Trafford ... ... ... ... | ·0432 | ·0032 more. |
| ,, ... ... ... ... | ·0291 | ·0109 less. |
| Churchyard, All Saints ... ... ... | ·0323 | ·0077 ,, |
| Smithfield Market ... ... ... ... | ·0446 | ·0046 more. |

CONFINED SPACES (*Manchester*).

| | Per cent. | More or less than standard, per cent. |
|---|---|---|
| Factory Mills ... ... ... ... ... | ·2830 | ·2430 more. |
| School Room ... ... ... ... ... | ·0970 | ·0570 ,, |
| Theatre Royal (pit) ... ... ... ... | ·2734 | ·2334 ,, |

OPEN SPACES (*London*).

| | | |
|---|---|---|
| Cheapside ... ... ... ... ... | ·0352 | ·0048 less. |
| Lower Thames Street ... ... ... ... | ·0428 | ·0028 more. |
| Top of Monument ... ... ... ... | ·0398 | ·0002 less. |
| Hyde Park ... ... ... ... ... | ·0334 | ·0066 ,, |
| Oxford Street ... ... ... ... ... | ·0344 | ·0056 ,, |
| Regent's Park ... ... ... ... ... | ·0304 | ·0096 ,, |

CONFINED SPACES (*London*).

| | | |
|---|---|---|
| Chancery Court (shut) ... ... ... ... | ·193 | ·1530 more. |
| ,, (open) ... ... ... ... | ·0507 | 0107 ,, |
| Strand Theatre (gallery, 10 p.m.) ... ... | ·101 | ·0610 ,, |
| Surrey Theatre (boxes, 12 p.m.) ... ... | ·218 | ·1780 ,, |
| Olympic Theatre (11·55 p.m.)... ... ... | ·1014 | ·0614 ,, |
| Standard Theatre (pit, 11 p.m.) ... ... | ·320 | ·2800 ,, |
| Metropolitan Railway between Gower Street and King's Cross ... ... ... .. | ·338 | ·2980 ,, |

OPEN SPACES (*Foreign*).

| | | |
|---|---|---|
| Lake of Geneva... ... ... ... ... | ·0439 | ·0039 ,, |
| Chambeisy ... ... ... ... ... | ·0460 | ·0060 ,, |
| Munich ... ... ... ... ... ... | ·0500 | ·0100 ,, |

IX. CARBONIC ACID THE MEASURE OF IMPURITY OF AIR.—If the exact measure of impurity of air was simply that expressed by the increased amount of carbonic acid, or the reduced amount of oxygen which it contains, it would not be long before the engineer, as well as the medical officer, could ascertain the exact condition of the air of any locality. But it is not exactly so. Though the increased amount of carbonic acid is some guide to the extent of impurity existing in the air, it gives no clue to the quality of that impurity, nor can we accept, as a rule, the assumption that as the quantity of carbonic acid increases, so will be the reduction of oxygen.

Dr. Parkes, however, gives the following reasons for taking carbonic acid as the index of impurity : "The carbonic acid which an adult man adds to the extent of about $\frac{6}{10}$ths of a cubic foot in an hour is not, within certain limits, an important impurity, but as it is practically in a constant ratio with the more important organic matter of respiration, and as it is readily determined, it is taken as a convenient index to the amount of the other impurities.

"Taking the carbonic acid as the measure of the impurity of the air vitiated by respiration (and by respiration alone), we have to ask what is to be considered the standard of purity of air in dwelling rooms? We cannot demand that the air of an inhabited

room shall be absolutely as pure as the outside air; for nothing short of breathing in the open air can insure perfect purity at every respiration. In every dwelling room there will be some impurity of air." . . . . "It appears from experiments made by Dr. de Chaumont and myself, that the organic impurity of the air is not perceptible to the senses until the carbonic acid (*i.e.*, the initial and the respiratory carbonic acid) rises to the ratio of ·6 per 1,000 volumes (·06 per cent.), or ·0006 in each cubic foot."

"Pettenkofer has now adopted the limit of ·7 measures of $CO_2$, and Degen ·66 measures per 1,000, as the amount when the organic matter simultaneously present becomes perceptible. I would propose then to adopt the amount of ·6 cubic feet per 1,000 volumes (·06 per cent.) of total carbonic acid (initial and respiratory) as the limit of impurity. I admit that I am not able to show by direct evidence that impurity, indicated by ·7 or ·8, or even one volume of carbonic acid per 1,000, and organic impurities in proportion, is injurious to health. We possess no means of testing such small quantities. Such a standard must be adopted, first, on the general evidence that large aërial impurities are decidedly hurtful, and that smaller amounts may be presumed to be so in proportion, although we cannot measure the action; and, secondly, on the fact that we have an obvious and simple measure in the effect produced on the senses, which gives us a practical line of demarcation we could not otherwise obtain."

But to ascertain the amount of carbonic acid in the air seems to the uninitiated not to be a very easy matter, even in the hands of chemists. To the engineer who is not acquainted with chemistry it is practically beyond reach, although Dr. Angus Smith (*Air and Rain*, p. 192) details several means of effecting what he terms "simple" tests, and which he calls the "minimetric" method. It is to be hoped that some self-recording instrument to correspond with the barometer, the thermometer, and the hygrometer, may yet be invented, by which the amount of carbonic acid in the air may be read off with simplicity.

X. Ground Air as affecting the Dwelling.—All air existing in and emanating from soil is rich in carbonic acid, associated with effluvia and organic gases, governed in quantity by the amount of animal and vegetable substances existing in the soil. Sulphuretted hydrogen is found under special circumstances. These emanations are the result of the very remarkable disinfecting powers of soil, which Dr. Angus Smith says will purify by oxidizing "sulphuretted hydrogen water, or its compound with ammonia, on a few inches of soil in a few minutes."—("*Air and Rain.*") They will continue to be given off from the surface so long as there exists beneath any organic matter to be oxidized.

Soils have different powers of decomposing organic substances without lessening the amount of carbonic acid gas evolved. Some soils, in fact, are purified by the air existing in them at the expense of the air incumbent upon them. Fleck, of Dresden, in his experiments on ground air, found that with an increase of carbonic acid there was a corresponding decrease of oxygen, and that the rate of decomposition is very much slower in clay (as every one would expect) than in sands and gravels, while the amount of carbonic acid given off by the slower decomposition taking place in clays was very much greater than from the more rapid decomposition in sands and gravels, though the latter was effected in half the time. [The unhealthiness of houses built on made soils for some time after the soils are laid down is no doubt to be attributed to the constant ascent of impure air from the impure soil into the warm houses above. The diseases which have been attributed to telluric effluvia are—paroxysmal fevers, enteric (typhoid) fever, yellow fever, bilious remittent fever, cholera, and dysentery.—*Parkes.*]

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### THE SITE OF DWELLINGS.



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## CHAPTER II.

XI. Ruling Considerations in Selecting Sites.—The architect rather than the engineer is generally the person consulted upon the sites of dwellings wherever they are erected, although there is no single object upon which the services of the sanitary engineer could be more usefully employed. In towns and villages, the sites of additional or substituted dwellings are generally fixed irrespective of the advice of any one.

In the case of isolated dwellings, however, where selection can be made, it is unnecessary to point out that adverse conditions in the site may render the best designed and best built structure unhealthy, for, as stated by Bacon, whose wisdom condescended to such social questions "he who builds a fair house upon an ill seat committeth himself to prison," to which he added the equally quaint but true remark, that he did "not reckon it an ill seat only where the air is unwholesome, but likewise where the air is unequal."

Aspect and shelter have each their bearing upon salubrity and equality of temperature, but neither the one nor the other has an influence so great as the condition of the soil beneath and surrounding the dwelling.

Dryness of site is essential to both these advantages, and the engineer has the power by appropriate *drainage* to render a sub-soil, which is naturally wet and polluted both dry and wholesome.

The meaning of the term "drainage," as pointed out by the author of Sanitary Engineering, is totally different from that of

"sewerage." An underground drain (the term being derived from the French *trainer*) means nothing more or less than a conduit intended to draw out of the land through which it passes the water which is in that land, and, as far as capillary attraction and natural retentiveness will permit, to remove the wetness caused by it.

The very reverse is the object of a "sewer" also derived from a French word, *issuer*, the precise meaning of which is a "conduit for the discharge of filth." A sewer should be used simply as a conduit to discharge its filthy contents as quickly and as completely as possible, without receiving any addition of liquid from the soil through which it passes, or allowing any part of its contents to escape into the soil. It has been the disregard, by engineers and by the draughtsmen of Acts of Parliament, of the true meaning and action of the drain and the sewer which has led to the present inferior condition of town sewerage throughout the country, and caused the sewage to be diluted by subsoil water by which it has been rendered unmanageable in after treatment.

By an appropriate *drainage* of the ground forming the sites of dwellings, and of towns and villages (which are the congregation of dwellings) not only may the soil be made absorbent of liquid filth, and capable by its aëration of oxidizing the nitrogenous matter which it absorbs, but, by the adoption of adequate depth of drains, the uprising of polluted liquid in the soil, and the consequent evolution of pernicious gases rising by evaporation into the air, and permeating the basements of dwellings, may be prevented. Moreover, I believe that as these points are established, and drainage is adopted, we shall go further and acknowledge a sensibly improved temperature of the air as an unmistakable consequence of under-draining the sites of dwellings. If I am right in these views, one of the first duties of the engineer, when carrying out sanitary works, is to render the ground upon which any dwellings stand free from subsoil water to within a recognised depth of their foundations. It is only by such means that the ground is made capable of supporting the incumbent outer air in such a state of purity (as indicated by the amount of carbonic acid it contains) that it shall always be available for the dilution of the air within dwellings.

Perhaps the most fruitful source of impurity of air in dwellings is in the damp condition of the ground immediately beneath and adjacent to them, which often becomes saturated with liquid filth by the too frequent practice of throwing the slops of the dwelling upon the surface of yards and gardens, or, what produces nearly as bad a condition, by heaping upon it solid house refuse of all sorts to be washed into the soil by the rainfall, and to give off effluvia from their accumulated heaps or to spread their minute particles in the air, and be taken into the lungs by respiration.

It is when such a state of things exists that malaria may be said to surround the dwelling, and render the outer air unfit for the dilution of the inner air. The malaria which prevails in certain countries can hardly be dissimilar in some respects to the air which exists over "excrement-sodden" ground and refuse covered yards, though the effect may be worse in a hot than in a moderately cool climate like our own. In both the absence of under-drainage is the primary cause of evil, and, in both, a soil aërated by under-drainage would, to a certain extent, oxidize the organic matters it contains, and greatly prevent the generation of miasma, and the diseases referred to in the closing paragraph of the last chapter.

XII. Naturally Dry and Wet Soils Compared.—In order to ascertain the influence of a drained soil upon human health, as indicated by the rate of mortality from consumption, we should examine the effect of a wet atmosphere and compare it with that of a dry one. It is found that the number of deaths from consumption in towns which are naturally dry, is so very much less than in towns which exist on a wet soil, that it is now believed by many that this disease is the off-spring of defective drainage.

Dr. Buchanan, of the Local Government Board, has very carefully investigated this subject, and reported upon it to the Medical Officer of that Board (Mr. Simon), who states in his general report (March 31st, 1868) that the investigation "confirms beyond all possibility of question the conclusions previously suggested, that dampness of soil is an important cause of phthisis to the population living upon the soil." Dr. Haviland of Northampton, Dr. Seaton of Nottingham, Dr. Fenton of Coventry, and many other medical authorities, all support, in a greater or less degree, the conclusions come to by Dr. Buchanan; but, perhaps, there is no more conclusive proof of the injurious effect of dampness of soil upon the health of a locality than that afforded some few years back in the district of Rochester, of which Dr. Sladen Knight says, "the annual death-rate of the Rochester Urban Sanitary District, calculated on the mortality of the three months ending 30th September last (1875), exclusive of deaths occurring in hospitals, was 15·910 per 1,000, whilst the annual death-rate of the drier portion of the city within the Medway district, *i.e.*, the part situate on the east side of Rochester Bridge, was but 12·494, and in the North Aylesford district, on the west side of the bridge, consisting principally of Strood, the greater portion of which is built on low-lying land and is frequently inundated by the tide, the death-rate was 23·800.

The importance of a dry soil as the site of human habitations is well authenticated by the report of Dr. Bowditch addressed to

the Medical Society of Massachusetts, U.S.A., which runs thus :— "Medical opinion, as deduced from the written statements of resident physicians in 183 towns, tends strongly to prove, though, perhaps, not affording perfect proof of the existence of a law on the development of consumption (in Massachusetts), which law has for its central idea that dampness of the soil in any township or locality is intimately connected with the prevalence of consumption in that township or locality."

But, though it is perhaps hardly possible to furnish more convincing proof of the advantage to be gained by draining artificially the subsoil lying beneath and surrounding dwellings, than by citing instances where nature herself affords the proof without any help from man, it will probably be considered more pertinent if I point out the fact that the strongest evidence yet afforded in support of this view has been given in cases where sewers, which were intended primarily for the discharge of liquid refuse, have acted accidentally in the double capacity of drains and sewers, and have drawn out of the subsoil the water rising up within it while discharging the sewage they were originally intended alone to remove. This is best shown by Dr. Buchanan's report "upon the Results of Works for promoting public health" (Ninth Report of Medical Officer of Privy Council, 1866), by which it appears that the general death-rate of Newport, in South Wales, was reduced 23 per cent., while the ailments known as "phthisis" were reduced 32 per cent. At Cardiff the general death-rate was reduced 24 per cent. and the death-rate from "phthisis" 17 per cent. At Salisbury the general death-rate was reduced 9 per cent. and that due to "phthisis" 49 per cent.

It must not be supposed, however, that I am advocating the construction of sewers to act generally in this way. I regard the practice as a species of engineering which we ought to avoid, inasmuch as the same apertures which let the water from the subsoil into the sewer will let the sewage out of the sewer into the subsoil, whenever the pressure from within is greater than that from without.

No better proof of the truth of the statement that a "*Sewer*" and a "*Drain*" have distinct duties to perform, which cannot be attained by *one* conduit, can be adduced than the fact, that in the city of Salisbury, referred to by Dr. Buchanan, the Corporation have determined to reconstruct a portion of their sewers, so as to avoid the influx of subsoil water; whilst at Hitchin, in Hertfordshire, the Local Authority have already substituted a water-tight main sewer in the place of one which served the double purpose.

And we must also remember that wherever sewage itself escapes, sewer gases will escape too. This practice no engineer can defend. Though good has come out of evil, we must never forget that the sewage and sewer air which escape may each rise up

in the ground in the neighbourhood of sewers, and render it, to use the words of Mr. Simon, "excrement-sodden," and the air "excrement-reeking." This is evidently the case in several of our sea-board towns, where the sewage is retained in the sewers by the rising of the tide, and which are thus converted into cess-pools.

While saying this I would not deny the fact that soil, where drained, has an almost immeasurable power of cleansing any liquid that may enter and pass through it, and thus defective work may be rendered harmless. In villages where shallow wells are retained for the supply of water, in opposition to the advice and in face of the analyses of the chemist, an aërated crust of soil, seven or eight feet thick, will do much to remove by oxidation the evil of pollution arising from the infiltration of organic matter.

XIII. WET SOILS INJURIOUS TO HEALTH.—We are not dependent upon towns only for illustrations of the benefit to be derived from lowering the subsoil water. Wide agricultural districts, containing isolated dwellings, have been so much benefited by drainage, that diseases which in former times constantly prevailed, have now ceased to exist. From the fens, ague, which had previously been the rule in every family during the spring of the year, has now been almost entirely banished by the works of Rennie and other engineers; although since it first ceased to exist, the disease has recurred, not at the same period of the year (spring) as before, but in the autumn of the year, a special circumstance, which Mr. Marshall, of Ely, the well-known naturalist, has explained as due to the fact that "the drainage had been carried beyond the point of prudence, so that in the summer months, and especially towards harvest, the fen ditches became nearly dry, and the consequence was that we once more got an exhaling surface, and a noxious effluvium arising from decaying vegetable matter." Mr. Marshall, in further explanation, adds that "this state of things is now quite altered, and the ague has again vanished owing to the farmers making it a rule to let water in from the rivers during the summer months, so as to 'keep a water' always in the fen ditches."

XIV. CAPILLARY ATTRACTION IN AND EVAPORATION FROM SOILS.—All soils are more or less susceptible to capillary attraction. In the chalk formation, water will rise from the level of complete saturation to a very considerable height above it, while a bed of the new red sandstone will be completely dry only a foot or so above the water standing in it. Wet soils of a more dense and retentive character (clays) do not give off vapour as copiously as free open soils kept wet by under-lying water; nevertheless, as long as there is any water below sufficiently near to keep them

moist by attraction, evaporation will continue, and in the end the amount of vapour given off from them will be much greater than in the case of free soils under similar conditions of outfall. Moreover organic substances existing in clays undergo decomposition slowly and without any diminution in the amount of carbonic acid gas evolved from them. It is for this reason that clay lands are termed *cold*, and may be considered comparatively insalubrious and therefore objectionable as the sites for dwellings.

From what has been said it may be taken as a rule that wherever ground is water-logged owing to the want of an outlet, whether the soil be an open gravel or a dense clay, it is unfit for the site of human dwellings until the line of saturation—*i.e.*, the subsoil water—is lowered, by drainage, to such a sufficient depth as not only to reduce evaporation, but to prevent the rising of moisture by attraction up to the cellar-floors and the foundations of the dwelling.

Nevertheless, if we examine closely into the condition of inhabited districts, we find considerable areas of water-logged land on the banks of rivers covered with dwellings, regardless of the height of the subsoil water beneath; and, if further, we examine into the rate of mortality, with special reference to deaths from lung diseases, rheumatism, and heart complaints, we see that they are increased in exact proportion as wetness prevails. It is found in all inhabited districts that those parts which have the natural advantage of a deep crust of open dry soil between the basements of dwellings, and the subterranean water level beneath, command a superior state of salubrity.

XV. Capacities of Soils for Retention of Water and Air, and the Special influence of Wet Soils upon the Sanitary condition of Cellars and Inhabited Basements.—All soils in positions to affect dwellings may be divided into three classes; first, those that are comparatively impervious, and will therefore resist absorption; second, those that are pervious and retentive, and absorb and give off water slowly; and last, those that are pervious and free, and absorb and give off water more rapidly.

In the first we include exposed rocks; in the second, clays of various qualities and degrees of density; and in the last, the sands, gravels, chalk, and mixed soils of various degrees of porosity.

In the absence of either natural or artificial drainage, all soils—retentive and free—hold water according to the interstitial spaces they contain. Without distinction, all soils thus filled with water instead of air, impart dampness to the walls with which they are in contact, while the "ground air" which arises from them in summer becomes injurious to health from its being more or less impregnated with putrescible matter.

"Impermeable" granites and marbles of the greatest possible density hold about a pint of water per cubic yard, while a loose sand will contain from 40 to 50 gallons per cubic yard. Ordinary red sandstone will hold 27 gallons per cubic yard.

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XVI. IMPROVEMENT OF TEMPERATURE CONSEQUENT UPON UNDER-DRAINAGE.—The advantage of lowering the sub-soil water, and of admitting air into the soil does not, however, end with the reduction of special diseases. This work has the effect of improving the temperature of the air incumbent upon the ground, as well as of raising that of the soil beneath. If the rain falling on the ground is absorbed and cannot escape from the sub-soil because no outlets exist to carry it away, it is evaporated from the surface; and, supposing 30 inches of rain to fall in a year on an acre of land, and its evaporation to be spread over the whole period, the daily weight of water evaporated would be rather more than 8¼ tons or 18,596 lbs.

An engineer will best realize the loss of heat, *i.e.*, the reduction of temperature resulting from the change of such a quantity of water into vapour, when he remembers that it would require "the combustion of about 24 cwt. of coals as ordinarily used under a steam boiler to effect the object" (*Josiah Parkes*); "cæteris paribus, the amount of water evaporated is proportional to the surface exposed to the air. It is much greater from porous solid surfaces kept wetted—as, for example, moist soil wetted by rain—than from the surface of water itself" (*Herschel*). Every grain of water evaporated, carries off with it sufficient heat to raise 960 grains 1 degree Fahr.

Mr. Buchan, of the Scottish Meteorological Society, has shown by his experiments "that the temperature of the drained soil has been raised in summer above that of undrained land to the extent of 3 degrees, often 2 degrees, and still more frequently a degree and a half; hence it follows that the advantage derived from drainage is, in many cases, the same as if the land had been transported 100 to 150 miles southward."

Dr. William Rankine showed (*Journal of the Scottish Meteorological Society*, 1865) that the mean temperature of land was raised by under-drainage at 10 inches from the surface eight-tenths of a degree, while the experiments I made at Hinxworth (*Journal of Royal Agricultural Society of England*, vol. xx, 1860) showed that in spring the temperature of drained land at 18 inches from the surface was 2 degrees higher than that of the undrained land at the same depth. The experiments of the late Josiah Parkes, near Bolton-le-Moors, showed an increase in the temperature of drained land over undrained bog, of 10 degrees at 31 inches below the surface. ["*On the influence of water on the temperature of soils*," *Journal of the Royal Agricultural Society of England*, vol. v.]

Professor Schubler's experiments at Tubingen and Geneva proved that rain falling on aërated (*i.e.*, drained) land, while supplying moisture, also supplied warmth and raised the mean annual temperature of ground 6 degrees at a depth of 4 feet; while, in support of the deep drainage of ground, Herschel states, on the authority of Quetelet (Mem. Acad., Brussels, 1836), "that the fluctuations of temperature beneath the surface grow continually less as the depth increases," and the difference between diurnal and nocturnal extremes becomes imperceptible at 4 feet below the surface.

XVII. Mode of Under-drainage required to dry the Sites of Dwellings.—The method of under-drainage necessary to lower the water level in wet lands to a proper depth will vary with the character of the subsoil. In water-logged *free* soils a single drain will often lower, at very little cost, the water level of a wide area. A similar effect has also been produced by the so-called "drain sewers" which have not only lowered the water in wells as well as in the soil, but have been known to cause settlement in houses at Norwich, by the removal and displacement of sand with the water beneath their foundations.

It may be taken, as a rule, that, in free soils, no advantage is gained by multiplying drains beyond the minimum number that will lower the subsoil water, and that they should be as far removed from buildings as possible.

In clay soils, numerous drains are requisite to overpower the retentive properties which such soils possess. The greater the number, the better will that purpose be fulfilled.

All drains should be made secure against the entry of vermin and the roots of trees, and the accumulation of peroxide of iron and other impediments; this will be done by carefully jointing the pipes with tarred gaskin and Portland cement, when passing through particular parts liable to such obstructions. Though it is desirable to avoid placing drains under any buildings, still they are sometimes essential to the perfect drainage of the sites of dwellings built on clay soils. When adopted, care must be taken to produce by the complete aëration of the subsoil that uniform disintegration, which counteracts contraction and expansion under different conditions of the atmosphere, and so avoids any injurious effect upon the superstructure.

That the maintenance of air freed from excessive evaporation by under-drainage, in conjunction with the removal of putrescible matters by proper arrangements and appliances connected with the dwelling, is an object of utmost importance, is shown by the highest medical authorities of the day, who declare that long continued exposure to bad air tends to the production of scrofula and consumption, of which latter disease, it is, as already stated,

probably an active primary cause; that it promotes enteric fevers; that it fosters ailments of the respiratory organs, such as catarrh bronchitis, and pneumonia; that it is frequently the cause of inflammation of the eyes, and that it adds to the spread of small-pox, measles, scarlet fever, and the like, while it renders the rapid cure of wounds and sores of all kinds a work of great difficulty.

I should not have laid so much stress upon under-drainage in contradistinction and in addition to sewerage as the work of the engineer, were it not that I am convinced that the present generation, which has adopted as an axiom the saying of Franklin that "public health is a nation's wealth," will be reproved by the next for not making the drying of the soil a fundamental requirement in sanitary works. I feel assured that as certainly as we of this generation are now engaged in removing from our rivers the polluting matters which the authorities of the last obliged our fathers to discharge into them, so will those who come after us lament with shame, and do their best to repair, the disregard paid by our present authorities to the drying of the sites of habitations, as one of the first considerations for the preservation of human life.

XVIII. Country Houses specially considered.—This chapter would hardly be complete were it not stated that there is no class of existing dwellings which more positively demands sanitary reorganization than that which comprises the mansions of our country gentry, which are generally considered from their position and surroundings to be free from the drawbacks attending urban residences. There are, however, no persons less ready to acknowledge this fact than those who occupy them.

The condition of our country mansions though occupying sites, which, in some respects, possess the advantages and are free from the objections which we have pointed out, has only to be examined to prove that a defective atmosphere, and a defective water supply must still exist in the majority of cases.

Up to this time the abstract warnings of medical authorities have hardly reached our country gentry, who, believing that they are surrounded by air naturally pure, and that their isolation frees them from the evils attending a combination of sewerage works, shut their eyes to the truth, that, by their own disregard of proper internal sanitary arrangements adverse conditions arise and evils are generated, which result in bad air and bad water. Surely there is no greater mistake than the encouragement of a belief in this immunity. The basements of many of our largest country mansions, occupied by the wealthiest of our landowners, are riddled with cesspools and threaded with brick sewers inhabited by rats. In a majority of cases, too, the water used for drinking, cooking, and washing will be obtained trom wells, sometimes under the

mansion itself, but more frequently in immediate proximity to putrefying matter collected in ash-pits and out-offices, or within reach of liquid escaping from external cesspools and sewers.

Whilst speaking of country houses it should be said that none should be without a plan of its sewers, drains, and water pipes, conspicuously placed for the observation of servants as well as superiors, and no pains should be spared to make every one understand that the private sewers and sanitary appliances of a country dwelling require just as much care and attention as the public sewers of a large town. Further, it is most desirable to leave as little as possible to be rectified by the village plumber, the only way of reducing his work to a minimum being simplicity of arrangement and accuracy of execution in the first instance, with a perfect record of pipes, &c., for after reference. In the absence of such a record as much money is expended in ascertaining the cause and position of anything wrong, as there is in putting it right when the defect is ascertained.

## CONTENTS OF CHAPTER III.

ESSENTIAL CONSIDERATIONS TO BE OBSERVED IN THE CONSTRUCTION OF DWELLINGS.



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# CHAPTER III.

[Having in the last chapter—which was devoted to the "*Site of the Dwelling*"—dealt with its "drainage" in its true meaning, and proposing in the next to treat of its "sewerage," it is now intended to specify certain considerations to which attention should in all cases be paid in the construction of the fabric itself.]

XIX. CONCRETE FLOORS.—After the water-level in the ground forming the site has been lowered by drainage (*see ante*, p. 17), every care should be taken to prevent dampness rising from that water-level into the basement floors, or up the walls through the foundations. To protect the basement floors from this evil it is desirable to cover the ground forming the base of the dwelling with a bed of concrete extending from outside wall to outside wall. This will not only prevent dampness and "ground air" rising from the underlying soil into the inhabited apartments, but it will also prevent any liquid refuse from sinking into the ground beneath to aggravate the pernicious character of the air which would otherwise rise from it. Such a covering of concrete is especially useful in preventing the rising of effluvia from any sewer that might be laid under the basement floor. Though contrary to the primary rules of sanitation, it is not always possible, especially in closely inhabited towns, to avoid laying sewers under the basement floors of houses; and where this is done special care should be taken to envelop them with concrete, so as to prevent any foul air that might escape from the joints of the pipes from being drawn into the house by the higher temperature of the rooms above. Under

ordinary circumstances an uniform depth of 6 inches will be a sufficient covering of concrete, the component parts of which should be ballast, consisting of broken stone, gravel, or burnt clay of a clean description, and Portland cement of the best quality, in the proportion of five of ballast to one of cement, with enough sand to fill up interstitial spaces.

XX. Damp Course.—To prevent moisture from rising up the walls of dwellings, it is now a general practice to build them on a foundation of concrete, the thickness of which should in no case be less than 12 inches. In addition to this base of concrete it is necessary to have a layer of impervious material within the wall itself, *i.e.*, between the courses of bricks or layers of stone work. This layer is ordinarily called the "*damp course*," and should act in the wall in the same way as the bed of concrete does under the basement floors. The proper height at which to insert the damp course in external walls is a few inches above the natural ground line, and in internal walls on a level with the bottom of the concrete. Damp courses are made of different materials;—sometimes a double course of slates bedded in cement is found sufficient;—sometimes, in very important and costly structures, a layer of sheet lead is placed throughout the whole length of the walls;—another material used is hot asphalte mixed with sand, laid $\frac{1}{2}$ or $\frac{3}{4}$ inch thick at the same height relatively to the ground line;—and perforated stoneware tiles bedded in cement have also been applied to the same purpose. These not only act as a preventative to the uprising of moisture, but also as a means of ventilating the spaces between the ground of the basement and the joists of the floor. A layer of cement alone is sometimes used, mixed in the proportion of one of Portland cement to one of clean sand, but, as it is apt to crack under superincumbent weight, it is not to be recommended.

XXI. Dripping Roofs and Dry Rot.—Dripping roofs, *i.e.*, those that are not provided with eave troughing, are a very common cause of dampness in the soil in immediate contact with the walls of dwellings. Many a house without a basement floor, and which would be otherwise dry and healthy, is rendered quite unfit for the habitation of the aged and infirm from this cause alone. In rural more than urban districts a disregard of this consideration largely prevails. That merciless enemy, "dry rot" (owing its name rather to the effect produced than to the cause), only takes possession of buildings where proper measures are not taken to secure a healthy base of structure. Dry rot is for the most part generated in a damp, close, and dark atmosphere; though when once in existence it seems to rise with extraordinary rapidity from its bed, and to spread vigorously

through timber and walls in all situations, dry or damp, light or dark. One great preventive of "dry rot" is an uninterrupted circulation of air throughout the basement, and between ceilings and floors. A good builder knows how to prevent the abuse of this admission of air by so laying his floor boards as to prevent the influx of cold air into dwelling rooms which might otherwise take place.

XXII. Hollow Walls.—Hollow external walls are sure preventatives to damp, and by their adoption in exposed localities the dwelling is not only rendered drier, but is made warmer in winter and cooler in summer. They may be built in either brick-work, stone, or concrete of a thickness dependent on the height or nature of the superstructure, but the space between the two walls should not in any case be less than 2 or 3 inches, with a carefully devised admission of outer air which should circulate through the hollow spaces. The method of tying the walls together by means of bricks (headers) is not to be recommended, for any existing outside moisture can be absorbed by the end of the brick, and through it conveyed inwards, thus neutralizing the benefit that would otherwise be derived. Ties of iron should be adopted in preference to those of any other material.

Different means are practised in different parts of the country for resisting the effects of driving rains. In principle, however, they do not commend themselves to the architect and builder as much as hollow walls. In some parts of Sussex and Hampshire, vertical slating of the external walls may be observed, whilst in Kent plain tiles are used in the same way, and present a much more agreeable appearance.

XXIII. Basement Floors under the level of surrounding ground to have Areas.—All dwellings in both town and country possessing basement floors under the level of the natural surface of the ground should have outside areas, or dry passages, between the ground and their walls. The omission of this precaution, especially in soils naturally wet or damp, necessarily produces an unhealthy condition within. In many cases an attempt to prevent dampness is made by building an outside wall which will provide a space between it and the basement wall of the dwelling, and this is arched over so as to form a dark outside passage. This is only a half-and-half remedy; the proper one is to build a wall thoroughly unconnected and allowing a space open to the air or covered with a grated top, so as to let the atmosphere freely circulate along the whole extent of the area. The floor of the area should be so laid as to allow water falling upon it to find its passage from the house to a central trapped cesspit. By such means any water will be discharged from the

area, without admitting any obnoxious effluvium from the sewer with which it may be connected. Small self-acting syphon flush tanks connected with a down pipe from the roof may be made a means of washing the floor of the area in times of rainfall, and at the same time flushing the outfall pipe from the cesspit to the sewer.

XXIV. No Cellar or Basement to exist in Dwellings built on Clay Soils.—In clay soils cellars and basement floors should be avoided altogether, for the retentive properties of clays will invariably cause dampness around the dwellings, and coldness within it, which neither under-drainage nor the existence of areas can overcome so effectually as to render them dry and comfortable. Dwellings erected on clay soils ought universally to be well raised *above* the ground surface, with free ventilation between that surface and the ground floor. It may, moreover, be taken as a general rule that no house built on any description of soil should be without space for ventilation between the earth or concrete and the joists upon which the ground floor is laid, and that such ventilation should secure a free and perfect circulation of air.

XXV. Ventilating Shafts in connection with Chimneys.—When setting forth the special provision to be made in the *structure* for securing a healthy condition of walls and basements, it may be stated that no arrangement will better conduce to successful ventilation than the construction of an extra flue in the principal stacks of chimneys, which shall serve—not for the passage of smoke—but for the extraction of foul air from the rooms on the different floors through which the stacks of chimneys pass. This extraction is secured by the higher temperature of the air within the shaft, raised, as it would necessarily be, by its forming one of a number of flues heated by fires beneath. All chimneys should be built as much as *possible inside* the dwelling and not against external walls, in order that the warmth they impart may not be lost. Under any circumstances it will be found of advantage that a ventilating shaft should be built in connection with the kitchen flue, which is always in use, when, by a perforated hollow cornice, or some such device, means can be taken to give an outlet from the rooms into the shaft without any objectionable appearance.

[The subject of ventilation being of paramount importance, it is treated separately in *Chapter* VI].

XXVI. As to the situation of Kitchen and Cooking Departments and the avoidance of Smells therefrom.—Without trespassing more than necessary on the province of the

architect, the position of the kitchen and scullery in both town and country dwellings and that of the ashpits, as the receptacles of kitchen refuse and garbage, can hardly be passed over. Experience is constantly showing that, by neglect of the primary rules which should regulate the position of these offices, the benefits aimed at in house sanitation are greatly neutralized, and that the necessary appurtenance—the dust-bin or ash-pit—is a frequent source of extreme annoyance, which can only be tolerated in proximity to dwellings by the strictest attention on the part of the scavenger. It cannot be too well recognized that plenty of air and light, cool and dry, are equally essential; whilst too much care cannot be paid to the means by which circulation of air without draught is attained, whereby all steam and vapours as they arise are carried off. It would seem impossible in town houses, where the kitchen must in nearly every case be placed beneath the living and sleeping rooms though speaking theoretically it should be *above* them all, to avoid altogether the uprising of the warm air and odours inseparable from cooking. Much, however, can be done to alleviate this objectionable state by outlets through the kitchen ceiling connected with tubes laid between the ceiling and the floor immediately above, which should communicate with the open air; by the judicious situation of doors and window in relation to the fire place; and by the selection of northern or eastern aspect where possible.

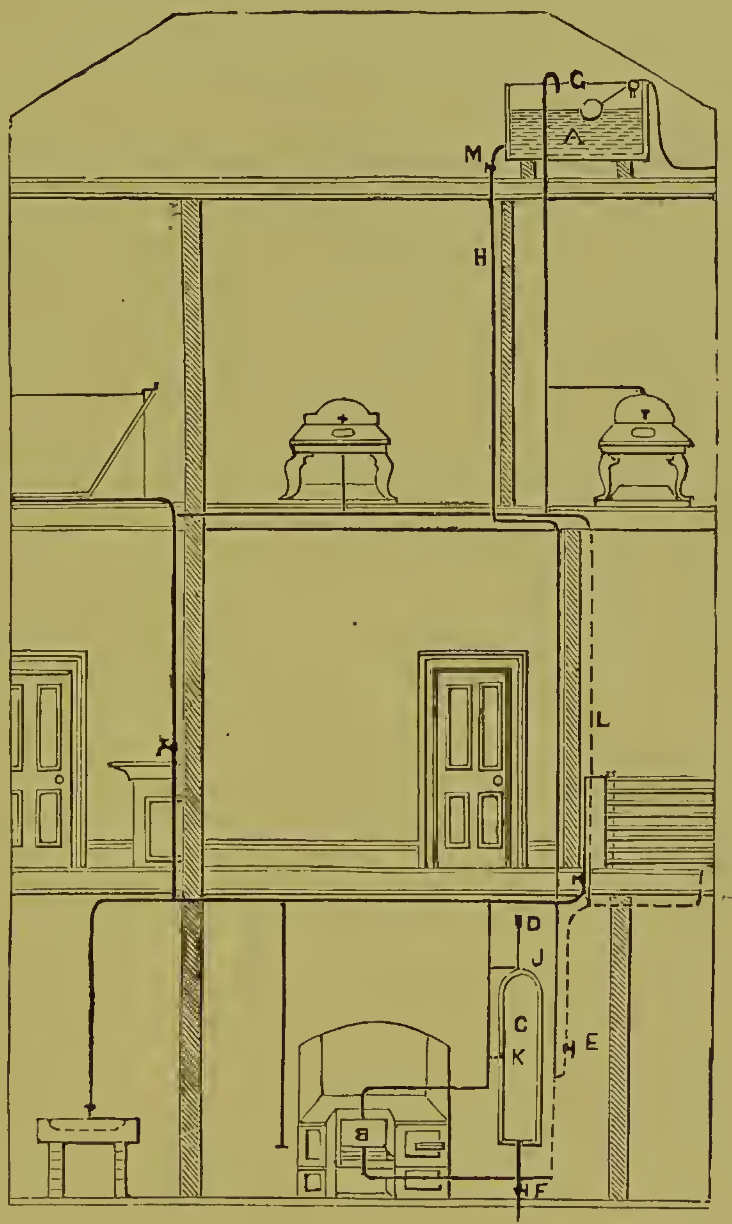
In country houses where these evils are almost invariably preventible disagreeable kitchen odours, nevertheless, are frequently as perceptible as in town houses. In the country no living or sleeping rooms should exist over these essential offices, but they should be separate, though attached, with space between ceiling and roof sufficient to allow of the gradual though certain escape of steam and vapours by proper ventilating arrangements made more perfect by the association of an empty flue connected with the chimneys; and the provision of properly devised doors to separate these offices from the main portion of the dwelling.

XXVII. Precautionary Measures to prevent Explosions of Boilers.—Though much loss, inconvenience, and discomfort is experienced from the bursting or cracking of kitchen boilers, by the sudden influx of cold water into them when in a state of extreme heat, occasioned by the stoppage of the supply pipes by frost or otherwise, it is not with the ordinary low pressure kitchen boilers of small houses that actual danger to life is to be apprehended. Explosions of a serious character generally occur with high pressure boilers used for the service of hot water to the upper appartments of dwellings.

Various have been the modes suggested for the prevention of accidents of this kind, and amongst them the first to be

noticed is the adoption of a cylinder placed in close proximity to the kitchen boiler (*see* Fig. 1) to act as a medium of connecting it with the main house cistern instead of a hot water circulating cistern with ball valves. It is made of stout copper and connected

FIG. 1.



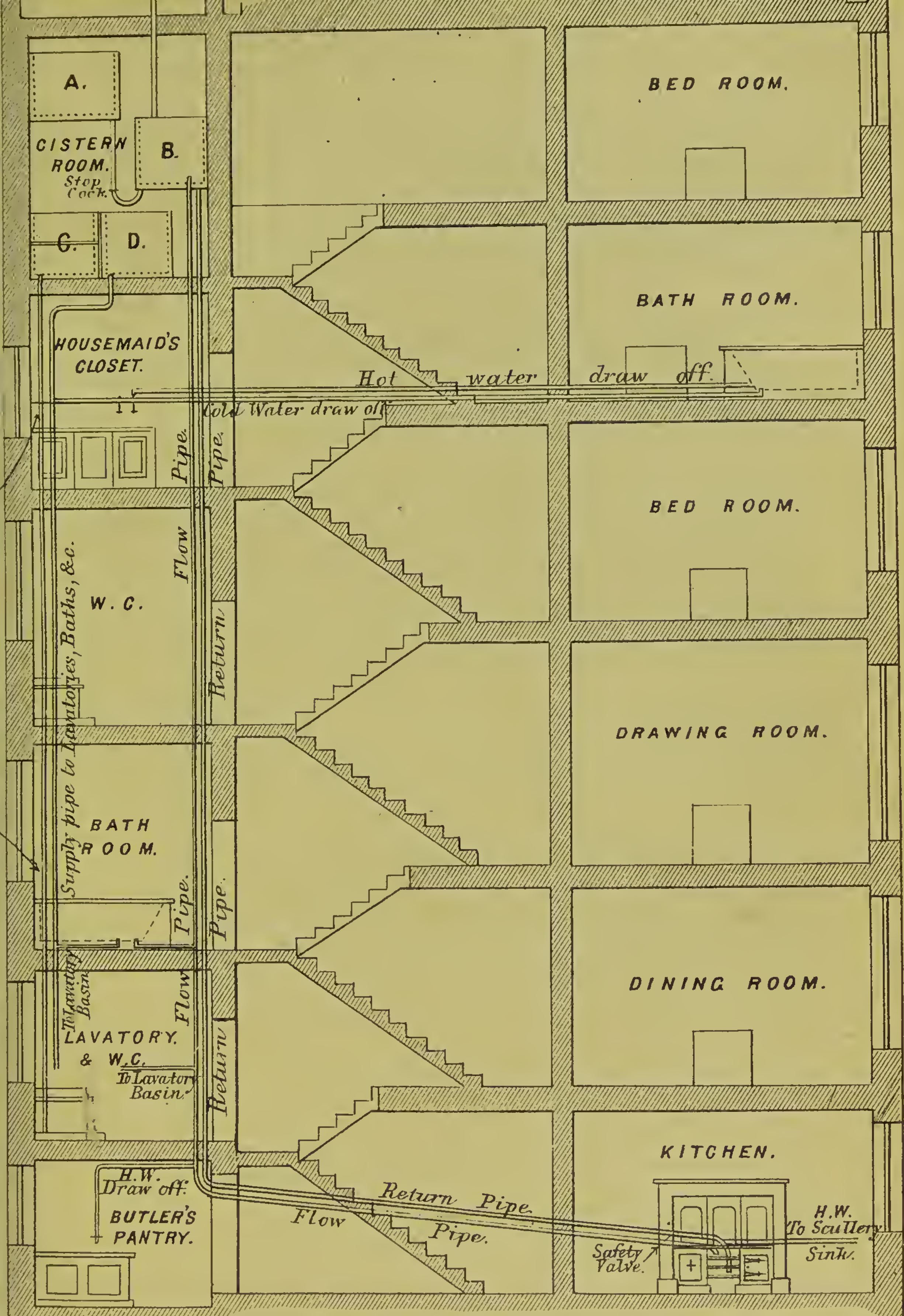

at its lowest extremity with the supply pipe from the house cistern. Two pipes also close to its base effect the necessary communication with the boiler. The water as yet cold flows to the boiler by the lower of these two pipes, and after being heated returns to the cylinder by the upper pipe. The cold water thus always remains at the bottom of the cylinder, and when hot, after its circulation through the boiler, naturally rises to the upper

portion of the cylinder—to the summit of which the hot water supply-pipe with all its branches is attached. No water is thus drawn from the boiler itself, and the supply is available to any height below the level of the water in the house cistern. With this arrangement it is impossible to drain the boiler dry, for the *exit* pipe from the cylinder being at the top of the cylinder, it cannot possibly be emptied, although the supply from the cistern above be entirely cut off, for a period of about three weeks. Valves are furnished to regulate or stop the circulation.

In other instances, where the hot water is drawn straight from the boiler itself, or its general supply made dependent on the efficient action of a ball valve in connection with it, the boiler can readily become dry, and explosion result. The above arrangement is most fully explained in a pamphlet by Mr. Grimshaw, F.C.S., of Manchester, on the management and arrangement of the kitchen boiler and water-pipes, which will amply repay persual; and Mr. Dyer, of Camden Town, has introduced this system into London.

Messrs. Bowden and Co., of 79, Elizabeth-street, Eaton Square, are the inventors of another method for the abolition of ball valves attached to hot water cisterns. In their invention they place the hot water cistern or cylinder not in the kitchen, as in the previous instance, where it must be a source of much additional heat—where it is least wanted—but in the uppermost story immediately below the house cistern, (*see drawing opposite*). They state that in their system the latter need not be disconnected from the former by any ball valve at all, but that by simply deflecting the feed pipe to act as an inverted syphon between the two in the manner shown in the illustration opposite, the water in the cold water cistern remains perfectly cold, whilst the water in the hot water cistern obtains the required temperature. The distribution of the hot water throughout the house is effected in a manner similar to that which generally prevails. Messrs. Bowden say that they have carried the system into successful operation in various houses at the west end of London, and that no failure in the object aimed at has been experienced, nor has the temperature of either supply, cold or hot, been in any way depreciated by the communication one with the other. If this invariably proves correct the invention is worthy of the highest commendation, for it effectually does away with all chance of danger without any attendant drawbacks, and the same principle will apply to low as to high pressure boilers.

To keep the pipes intended for hot water from freezing during severe frosts, Mr. Grimshaw, in his pamphlet says, that "*hot*-water pipes cannot freeze, *so keep them hot*. This is the best plan; keep the usual fire in the kitchen range, draw off at intervals a little hot water, then all the hot water pipes will be kept at least *warm*, the




A._Cold Water Cistern to supply Hot Water Cistern only.
B._Hot Water Cistern.
C._Cistern for W.Cs. only.
D._Cistern for Lavatories, Baths & Housemaids Closet.

The cold water supply to sinks in Butler's Pantry, Scullery, and Servants' Hall, is from a cistern in basement.

G. Bowden & Co. Builders, 79 Elizabeth St. Eaton Sq.re S.W.

cold water pipe from cistern to cylinder will be kept in motion, and the ball tap and pipe also. At night damp the fire down with 'slack,' and ashes slightly wetted, so that it will keep in till morning or nearly so, and after damping down run a quart or so of hot water from the tap to give a final move to the pipes."

As regards safety valves for boilers, they are of numerous kinds, but with arrangements such as have been just described, there can be no need for any.

With other arrangements, however, they may be advisable; and the best form of valve is what is termed the "dead weight valve," or one in which the weight acts directly with no intervening lever.

Safety plates are now becoming generally adopted. These consist of a sheet of copper or iron rivetted to the boiler, and of such a thickness as will cause it to give way to a pressure somewhat greater than the weight of the column of water between cistern and boiler, which it is ordinarily called upon to bear.

The following general rules, which are within the reach of all, should be universally adhered to, and if followed the possibility of explosion and danger to life would be reduced to a minimum.

(1.) The boiler should be of *wrought* iron properly tested before use.

(2.) The boiler should be periodically inspected, and if necessary cleaned.

(3.) The pipes in connection with the boiler should be carried up within the dwelling, and not against an external wall.

(4.) The cisterns should be placed in a position easy of access, and well protected from frost.

(5.) And that, where there is a safety valve, it should be such as can be easily adjusted, and of a description sensitive to variations of pressure; and it should be fixed in an accessible place, where it can be readily taken to pieces and refixed.

## CONTENTS OF CHAPTER IV.

### EXTERNAL SEWERAGE.



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## CHAPTER IV.

XXVIII. Definition of Sewage.—The Sewage Committee of the British Association have declared that the term sewage applies to any refuse from human habitations that may affect the public health (*First report of the Sewage Committee of the British Association*, 1869), and this broad acceptance of the term may be fully justified.*

When considering the work of the engineer in relation to the dwelling, it will be better to divide sewage into two parts:

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* Sewage is a very complex liquid ; a large proportion of its most offensive matter is of course human excrement discharged from water-closets and privies, and also urine thrown down gully-holes. But mixed with this is the water from kitchens containing vegetable, animal, and other refuse ; and that from the washhouses containing soap and the animal matters from soiled linen. There is also the drainage from stables and cow-houses, and that from slaughter-houses containing animal and vegetable offal. In cases where privies and cesspools are used instead of water-closets, or these are not connected with the sewers, there is still a large proportion of human refuse in the form of chamber slops and urine. In fact sewage cannot be looked upon as composed solely of human excrement diluted with water, but as water mixed with a vast variety of matters, some held in suspension, some in solution."—*Rivers Pollution Commissioners.*

1st, the refuse of which the medium of removal is water; and 2nd, the solid refuse and garbage conveyed to the ash-pit or dust-bin, and the excretal contents of the privy or outside closet the removal of which may be effected by mixture with earth, ashes, or other dry material.

The first or liquid sewage will be discharged by the sewer; the second or solid refuse will be removed by hand.

The excrementitious products of domestic animals housed in buildings, etc., attached to dwellings cannot be altogether excluded from consideration; but as they only remotely affect human health, and are generally dealt with in a ready and independent manner, much reference to them in this work is not necessary.

XXIX. The Mode of disposing of the Liquid Sewage to be determined before laying out External Sewers.—In towns and villages, where an available system of sewers and sewage disposal already exists, the liquid refuse of all dwellings should be discharged into the nearest "common sewer" by a private communicating sewer. Its ultimate disposal will then be left to the sanitary authority of the district, and the owner of the dwelling will thus be relieved of all difficulty on that question. In this case the direction of the private outfall sewer will depend upon whether the dwelling stands alone, where it may follow any course which the owner may direct, or whether it forms one of several dwellings where a combined arrangement designed to collect the liquid refuse has been adopted. As already stated, in thickly crowded towns the passage of sewers under dwellings cannot be altogether avoided, though much may be done by combined back arrangements, in the way pointed out by Mr. Rawlinson, and exhibited in his published "Suggestions," to obviate the practice.

In essentially rural districts where dwellings are isolated, the mode of disposal not having been pre-determined by a local authority assumes a much more difficult aspect, though it must not be taken for granted that isolation means exemption from statutable obligations. The truth of this remark becomes more manifest directly it is acknowledged that all liquid refuse—come from whence it may—must be cleansed and freed from polluting matters before it finds its way into the river or watercourse which nature has provided for its ultimate reception.

With succeeding Governments hesitating from a wish in no way to injuriously affect the interests of local trades, to protect those streams which form the water supply of localities, there is much disinclination on the part of country gentlemen and occupants of isolated dwellings in rural districts to acknowledge their obligations to conform to the sanitary laws; but they cannot be long evaded, now that every rural district acknowledges a

sanitary authority, and is amenable to the same sanitary law that governs large communities.

By the 17th clause of the Public Health Act, 1875, it is enacted, "That nothing in that Act shall authorise any local authority to make or use any sewer, drain, or outfall for the purpose of conveying sewage or filthy water into any natural stream or watercourse, or into any canal, pond, or lake until such sewage or filthy water is freed from all excrementitious or other foul or noxious matter."* As soon as the obligation imposed by this clause, which unfortunately for the country aims negatively rather than positively at the purification of rivers, is acknowledged in rural districts, those persons occupying isolated dwellings will discontinue their present mode of discharging their liquid refuse either into filthy cesspools or directly into streams. The law will, in truth, be enforced by inspectors of nuisances when they have been educated to their duties, or by medical officers of health, who will become more vigilant as they gain experience, and who will feel bound in obedience to the general law to allow of no exemptions.

The chief question to be solved, therefore, is how the sewage of isolated dwellings may be so freed of noxious matter as to be admissible into rivers or watercourses.

XXX. Modes of Treatment inapplicable to Isolated Dwellings.—The various processes to purify sewage by subsidence or chemical precipitation are, even if applicable to towns, *never suitable* in the case of isolated dwellings. At the best, the former treatment invariably, and the latter frequently, would only *clarify* without in reality *purifying* the liquid sewage, and as clarification is not the only proof of fitness required for the admission of liquids into running streams, it will be obvious that no occupant of an isolated dwelling would be justified in adopting either.

Chemical processes which may possibly effect purification involving the purchase of ingredients and careful manipulation must always be attended with considerable expense, which is not recovered in the value of the product, and though a large community may find it expedient to suffer loss, individuals will always avoid it if they can. The *clarification* even of liquid refuse can only be maintained by the aid of labourers and servants, which clarification may at any time fail, subjecting the occupier to the penalties

* By the Rivers Pollution Prevention Act (39 and 40 Vic. c. 75) which has now become law, it is laid down that no sewage or noxious matter shall be discharged into a river or watercourse until it has been freed of its polluting ingredients by *the best practical and available means*. The Commissioners suggested that effluent sewage to be admissible into rivers (after cleansing) should contain not more per 100,000 parts than ·3 of organic nitrogen and 2 parts of organic carbon.

set forth in the 69th Section of the Public Health Act, 1875. These latter observations bear greatly on the question because every day's practice tends to show how little reliance can be placed on service, especially when employed in a distasteful duty, which labourers are glad to escape. It is much to be regretted that the Local Government Board cannot come to some decision after the many years' experience they have had of the inefficacy of chemical and mechanical treatments which should be a guide to householders who are desirous of doing what is required by the law.

XXXI. MODES OF TREATMENT AVAILABLE FOR ISOLATED DWELLINGS.—By reading the interpretation clause of the Public Health Act, 1875, it will be seen that the Legislature has not helped in removing the difficulties of this important branch of the sewage question, for it contemplates that the liquid refuse of isolated dwellings may be discharged into some *cesspool or other like receptacle* (when not received into a common sewer), where it would be subjected to such treatment as would free the occupants of liability to penalties for nuisance or river pollution. What that treatment shall be, under the various conditions which will arise, has been left to those who are immediately concerned. The question, in fact, has been studiously avoided up to this time by all parties alike, and the disposition of individuals to deal with it has therefore gradually become less. Can this be wondered at when all practical minds regard "cesspools," which the Government acknowledge, as evils of the worst order?

If the sewage be taken to a considerable distance from the dwelling to a "cesspool," sump, or other like receptacle purposely made to allow the liquid to escape out of it into a porous soil, such as the chalk, the red sandstone, or one of the free oolitic beds, the sewage will probably soak away down to the subterranean water level at whatever depth it may be. If it be great, no mischief whatever may follow.

If, on the contrary, the water level be near the surface, then the cesspool and its unseen outpourings—though relieving the occupier of the dwelling of considerable temporary trouble—will remain liable to all the objections to which common privy-cesspits are admittedly subject.

In many instances these "dumb" wells, which have been adopted in a great number of places where the sanitary authorities of urban and rural districts have been unable or unwilling to cope with the disposal of the sewage of their districts, have become a concentrated evil of the worst description. In instances where the subsoil is of a character not to absorb the sewage—such as a clay soil—as it has escaped from the cesspool, the occupier has been compelled to lift it to the surface, and distribute it by hand or hose over grass, arable, or garden land

near at hand, or cart it away to a distance. This treatment is subject, however, to the irregularity attending all manual work, and generally results in a nuisance.

Where, however, the grounds attached to dwellings—especially country mansions and large institutions — are sufficiently wide in area, and possess surface capabilities to allow of the application of the sewage direct to land, without the same dependence upon personal attention as in the treatment to which I have just referred, such a disposal will be altogether free from objection, —the primary condition essential to success being that the whole liquid dealt with shall percolate through a sufficient quantity and depth of soil to ensure its ultimate discharge in a cleansed condition. To ensure this, the natural or artificial under-drainage of the land to be dealt with is essential whether the sewage be applied by way of surface irrigation or by intermittent downward filtration; and clay soils should, as a rule, be avoided, though with great care they may be made available.

The superficial extent of land which it may be desirable to appropriate to the purification of sewage discharged from private dwellings will depend upon the character of the soil, the area at command, and other local circumstances. With suitable soils which have been rendered uniformly percolative, and occupy a favourable position in relation to outfall, &c., the quantity of land utilized may be increased or reduced, and irrigation or intermittent downward filtration adopted just as it may be found expedient.

Intermittent downward filtration was originated by Dr. Edward Frankland, F.R.S., who, after making certain laboratory experiments, stated that a cubic yard of aërated soil would satisfactorily cleanse, so as to be admitted into a running stream, from 4½ to 10 gallons of sewage, each twenty-four hours according to the character of its constituents. This result he declared to be due to the fact that "such a filter is not a mere mechanical contrivance; it is a machine for oxidizing, and thus altogether transforming, as well as for merely separating the filth of dirty water." If intermittently brought into use, such a filter performs an act of respiration "copying on an enormous scale the lung action of a breathing animal, for it is alternately receiving and respiring air, and thus dealing as an oxidizing agent with the filthy fluid which is trickling through it."

With reference to intermittent downward filtration, I may here state that Dr. Frankland declared as the result of his investigation that the sewage of 3,300, or say 3,000, persons might be cleansed by intermittent filtration through one acre of suitable land drained six feet deep, but that the process would, he thought, be open to certain objections. My long connection with agricultural works of all kinds enabled me to appreciate Dr. Frankland's theory. I suggested as the means of overcoming the objections anticipated,

and in order to secure an undoubted permanency of effect and continued freedom from everything like nuisance, that instead of using the same land for filtration one year after another, it should be used every third year, so as to give two years' rest. It is true that this rotation necessitates the use of three acres instead of one for 3,300 persons, *i.e.*, one acre for 1,100 persons; but the increase of quantity still leaves the process the simplest and cheapest mode of purifying sewage hitherto known, and one particularly available for isolated dwellings and institutions wherever land is difficult to obtain.

A considerable amount of practice following this suggestion has positively shown that if the area of land at command be limited, any quantity not less in proportion than one acre for 1,000 persons will be sufficient for the perfect cleansing of the liquid refuse discharged, while some return in the shape of vegetables or grass from the land so used may be obtained. If, however, the surface available be unlimited, the sewage may be applied by way of surface irrigation in the proportion of one acre for 100 persons, with the probability of a more profitable return from the vegetables grown than in the other case. Any quantity of land between these two extremes which the circumstances may prescribe may be utilized with satisfactory effect.

With these facts before us, it can be well understood that such is the purifying power of natural soil where sewage percolates evenly through it, that it is not at all impossible that the area of land which would suffice to free the liquid refuse of a large mansion from all foul or noxious matter, and render it fit to be discharged into any natural stream or watercourse, need be but a very few poles, if that area is specially prepared for the purpose.

I can bring under your notice a very good illustration of what can be done in this way in the form of a letter which I received from Baron von Liebig, very shortly before his death. It tells its own tale so well that I will give the translation of it without further preface.

"Receive my best thanks for your letter of the 3rd instant, and for the paper on *Intermittent Filtration through Natural Soil.* I have read this with great pleasure and real satisfaction. You have utilized in the most effective way for the service of populations the natural law which I laid down in my book, the *Natural Laws of Husbandry*, pp. 113 and 114. Your plan for the purification of liquid sewage and the removal of its injurious qualities, as well as the technical execution of the plan, and the use of sewage as manure, are alike excellent, and I only wish that use may be made of it in other places. In Silesia for some years past the best use has been made of your principles in the Beet-root Sugar Manufactory of Herr von Rath. In the neighbourhood where this manufactory is situated there is a want of spring water

and of water generally, and this want has called forth the following arrangement. All water that has been used in the manufactory, and generally all waste or foul liquids, are discharged on to a well-drained piece of land close at hand, and the filtered effluent water is collected in a well. It is pure and clear, and it is again raised by a pump, and used in the manufactory as fresh water. Enormous crops of grass are obtained from the piece of land which serves for filtration."

In order to avoid even the idea of nuisance, the land selected for sewage treatment should be situated at a distance of two furlongs or more from the dwelling, though in the cases of certain public asylums and hospitals much less than that distance has been found by experience to be quite sufficient.

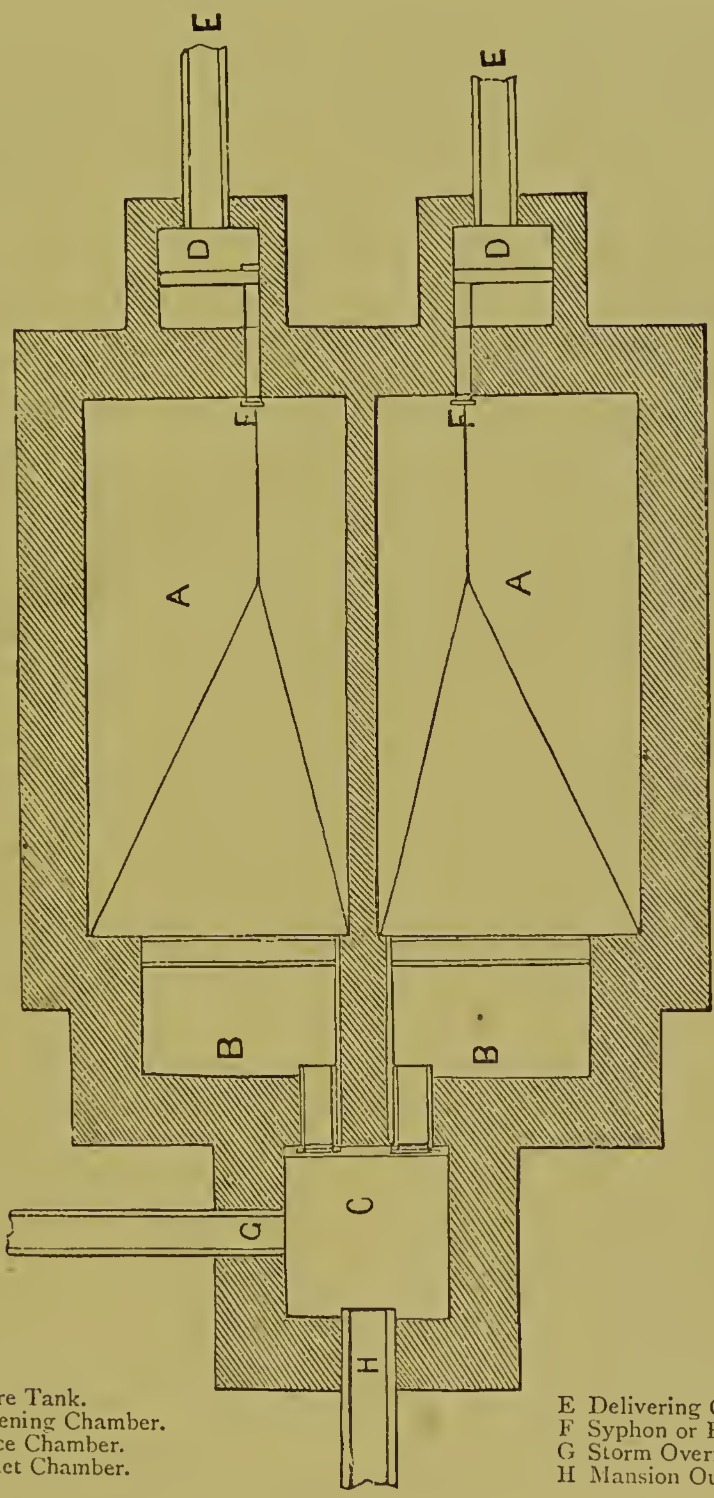
XXXII.—Means of Collecting the Liquid Sewage of the Dwelling, and of Regulating its Distribution over Land.—The great, if not the only difficulty which is practically experienced in disposing of the liquid sewage of isolated dwellings, institutions, and villages upon land, is that due to the irregular and comparatively small outflow which at different times of the day is discharged from them, and which has rendered it necessary to devise a means of collecting the sewage and dealing with it in fixed quantities. It was with this object that I devised the Automatic Regulator in order to utilize the sewage on the surface of land, and as I know of no other arrangement by which this important duty is accomplished I will shortly describe it. It consists of a tank (singly, or in duplicate, as in the illustration, Fig. 2) of such capacity as to hold either the third, or the half, or the whole of the sewage discharged each day from the dwelling, the quantity to be collected being determined by the character and amount of sewage to be dealt with in the day. The land to receive and absorb this quantity of sewage must be at such a level below the outlet from the tank (*see* Fig. 2A), and so prepared as to allow of its being distributed evenly over the surface. The tank itself should be as deep as can be arranged, for the deeper it is the less will be the superficial space it will occupy, and the less chance there will be of escape of effluvium.

To effect the discharge of the contents of the tank *automatically* at any time of the day or night, a syphon or float (*see* letter F) is fixed in it, which must come into action directly the sewage rises above its crown. Thus the water is delivered to the land in equal quantities and at desirable intervals. Where necessary the soil should be carefully under-drained and prepared, so as to secure thorough filtration and consequent oxidation of the liquid.

With this system the smallest amount of labour is required, occasional supervision only being required to keep the screens in

the chamber B clear, to remove any sludge that may accumulate, and attend to the distribution of the water.

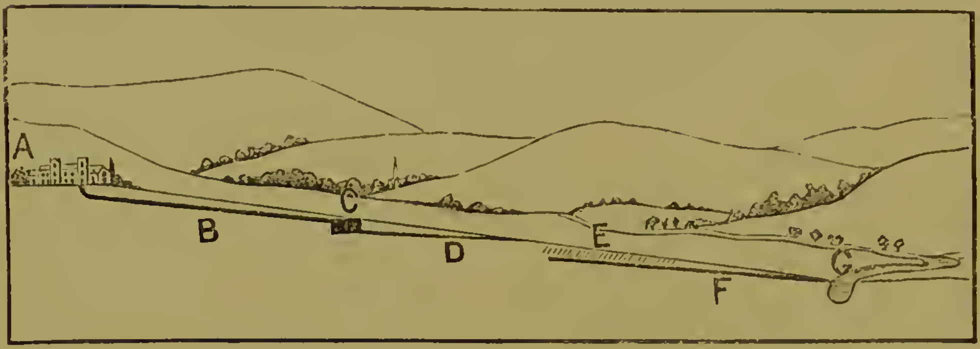
FIG. 2.




A Metre Tank.
B Screening Chamber.
C Sluice Chamber.
D Outlet Chamber.

E Delivering Conduit.
F Syphon or Float Outlet.
G Storm Overflow.
H Mansion Outfall Sewer.

FIG. 2A.




A Village or Mansion.
B Outfall Sewer.
C Regulator.
D Sewage Delivering Conduit.
E Land to which sewage is applied.
F Under-drain.
G Outfall stream or watercourse.

The regulator has now been in successful operation at various villages and mansions in different parts of the country for several years, and until recently it has been fitted with either the ordinary syphon, or a float which comes into action in a similar manner to the syphon. But latterly it has been found that Mr. Rogers Field's annular syphon (*see* Fig. 19), which experience has proved to be free from certain irregularities to which both the former contrivances were occasionally liable, can be usefully substituted in their place.

XXXIII.—REASONS WHY SUB-IRRIGATION OF LAND SHOULD BE AVOIDED.—Sub-irrigation has been suggested as another means of disposing of the sewage of dwellings. It has been received with favour by some persons and has been adopted on free soils with apparent success, but as the liquid is distributed through the subsoil by underground pipes which are out of sight, the process is liable to objections which sanitarians cannot fail to recognise and appreciate.

The foremost of these objections is the fact that the distributing pipes must sooner or later become choked with the minute solid matters held by the liquid refuse in suspension, and when this is the case an "excrement sodden" condition of soil is produced. A stoppage can only be detected by positive signs of wetness on the surface, and not until the evils produced by exhalations from excrementitious matter may have gained an ascendency. Mr. Rogers Field has done much to overcome these objections. The drains by which he effects the distribution of the liquid consist of common agricultural drain pipes laid some 10 or 12 inches below the surface on a continuous bed of larger half-pipes.

This bed is not disturbed when the pipes are taken up to be

cleaned, which ensures their being readily re-laid in true position The sewage flows out of the joints into the soil and feeds the vegetation, and the concentration of the flow effected by the sudden discharge of a regulator or flush tank with which the pipes are connected, forces the liquid rapidly along them.

Sub-irrigation, however, is a process faulty in principle, as it feeds vegetation by the upward rising of moisture, accompanied by evaporation with all the chilling influences which are so injurious to vegetation as well as to human beings.

In deference, however, to the wide experience of Mr. Rogers Field, and to the practical results obtained by Mr. Waring, of Newport, U.S.A., who has adopted this means of sewage utilization in various instances in America, it is only right to append an extract from one of this last-named gentleman's letters on this subject.

In it he says, "I am carrying out the principles of sewage utilization here to some extent, not, however, in surface irrigation, but in the distribution of screened sewage by means of flush tanks of larger capacity, and of sub-irrigation by draining tiles laid about 10 inches below the surface of the ground. Some of this work dates back to 1869, and in one instance I have disposed in this manner of the sewage of a village of about 1,500 inhabitants; and in another of the outflow of a prison producing about 30,000 gallons per day. In every instance the result has been most satisfactory, and I have large works of the same character now in hand."

XXXIV.—As to the Removal of Solid Refuse.—The solid portions of the sewage of all well-ordered dwellings, whether they stand singly or in the street of a town, consisting of animal and vegetable refuse, dust, ashes, and other substances forming kitchen waste, as well as the excretal refuse from earth closets, require only careful collection and frequent periodical removal to render them free from nuisance. If this work is performed by a public scavenger, under the directions of an urban or rural sanitary authority with proper facilities for collection, the duty may be thoroughly and readily performed; but in the absence of systematic arrangements, whether public or private, evils will arise of the worst character. In isolated dwellings, where pigs are kept at some distance from them, and where gardens exist for the profitable application of manure, but little difficulty need be experienced, though it should be borne in mind that nothing is more offensive than pig-styes badly attended to within reach of the olfactory organs. Manure from stables and cowhouses, as well as that produced by other animals, as rabbits, goats, &c., if properly collected and preserved, being the product of graniverous animals, need never be a source of injury to health. The same, however, cannot be said

of the washing of dog-kennels, than which few things can be more pernicious. Good trapping and frequent flushing are essential.

Pits for the collection of household garbage before removal should never be built of a size larger than necessary for the requirements of the dwelling, and they should be situated in accessible places to facilitate removal. In every case they should be well covered over to shield the contents from the sun and rain, as they emit but little smell so long as they are kept free from moisture. In town houses the periodical and frequent emptying of ash-pits is indispensable. All ashpits should be built of non-absorbent bricks or stone. The floor should never be below the ground level, and should be paved with a hard material.

A receptacle for the collection of ashes, separate from that for kitchen refuse, is most useful. It should be fitted with a screen to sift out those ashes which are capable of re-burning.

As before stated, the excretal refuse from earth closets should be removed with rigid regularity, and where there is no proper receptacle for collection, and no real means of removal, it should be dug into the soil and so utilized, though its fertilizing value is very trifling.

XXXV.—The Outfall Sewer of the Dwelling.—This sewer by which the liquid refuse of the dwelling is discharged into the public (common) sewer, or into the "cesspool or other like receptacle" (such as the regulator just described), should conform to the following conditions :—

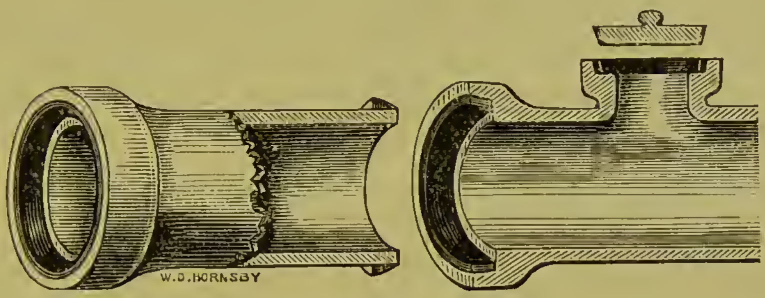
(1.) *Construction.*—It should be constructed of stoneware or earthenware glazed pipes, jointed in such a manner as to form a perfectly watertight conduit, resisting alike the influx of subsoil water into it, and the efflux of sewage out of it, and resisting also the intrusion of the roots of shrubs and trees, which manage in the most extraordinary manner to find a passage into both sewers and drains through the joints. Puddled clay, contrary to general belief, fails to secure a perfect joint near roots which run in search of water, and it also fails where the pipes are laid in a dry soil in which drought and evaporation will cause the clay to crack and to destroy its watertight condition. Its use is as equally objectionable in a country mansion as in a town house. When cement is used, too great care cannot be exercised to prevent cracking, as minute rootlets creep through the least fissures. Tarred gaskin and cement are probably the best materials for rendering ordinary socket joints watertight, and at the same time capable of resisting the intrusion of tree roots if supplemented by a band of concrete.

There are several descriptions of pipes with jointing material attached to them—the object of which is to obviate the necessity of using either cement or clay in securing a watertight condition. The material is a bituminous compound (amalgam) which is cast in

rings upon the pipe, and being in true circle, if carefully laid, the junction of one pipe with another is readily effected.

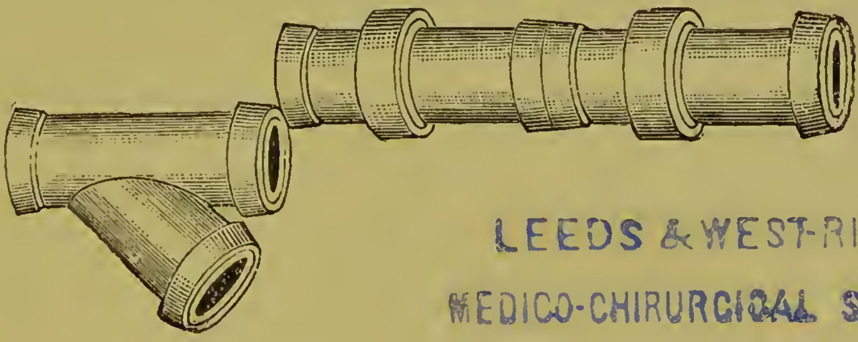
Those known as "Stanford's Patent Joint Pipes" have much to recommend them. It is the practice when using them to grease the joints and by a twist of the pipe to fit them closely together. Fig. 3 shows these pipes.

FIG. 3.




There is a description of pipe having the same kind of material for the joint, distinguished as "Roberts' Patent Joint," "constructed on the principle of the wedge" (*see* Fig. 4). Each joint is covered by a collar lined with the amalgam, which is passed over the ends of the pipes required to be connected. The ends of the pipes are also loaded with the same material moulded in a reverse direction to that in the interior of the collar. The collar can be removed without breaking the pipes, and by simply sliding it back any junction can be made at a trifling cost.

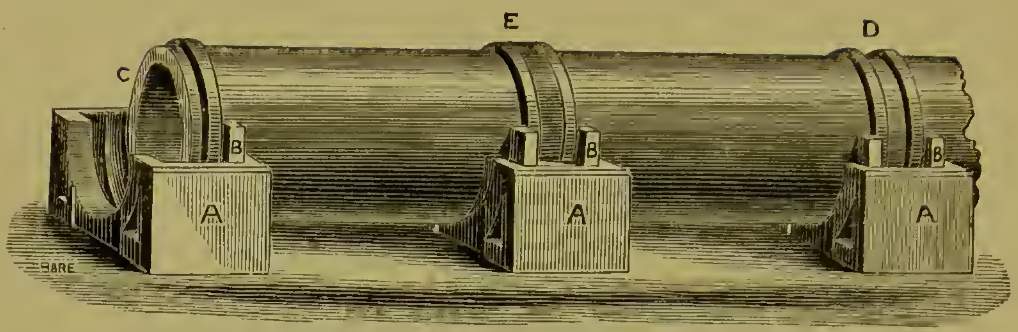
FIG. 4.





And there is a mode of securing a watertight junction in which the material used is liquid cement. The invention is best explained by the illustration, Fig. 5; and its advantages are stated to consist in the junctions being less costly than other watertight joints, whilst they are also as applicable to gas and water as to sewage. The patentee declares that the joints of 15 inch stoneware pipes have been tested up to 200 feet head of water, equal to 86 lb. pressure on the square inch, without the least sign of giving.

Fig. 5.



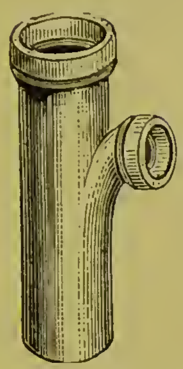

To provide a means of removing obstructions and to effect junctions in pipe sewers after they are laid, some engineers recommend the laying of *half pipes* with half sockets, and in exceptional cases where clay puddle may be advantageously used instead of cement they may be in their proper place; but seeing that the halves must conform to the same watertight condition as the rest of the sewer, it is obvious that they are inapplicable when the jointing material is cement.

The advantage of a watertight sewer will commend itself to the occupiers of dwellings by the fact that if the sewage finds its way out of an imperfectly constructed sewer, the sedimentary particles will be left behind in the sewers to collect in, and ultimately choke, up the pipes.

(2.) *Position or Course.*—It should in no case, where it can easily be avoided, pass under the dwelling. Where, however, in crowded towns this cannot be avoided it should, if possible, be laid under a passage or paved floor, and it should be bedded in concrete and provided with a ready means of inspection without breaking the pipes, by means of lidded or capped pipes. Any sewer thus passing under the dwelling, should be carried completely through from outside to outside, having at each end a trap with grated covering, so as to gain thorough ventilation, *i.e.*, a passage of air along its entire length. At the upper end it may also, where practicable, be provided with a means of flushing in order to keep the pipes clear of deposit, and the pipes themselves should be carefully relieved from pressure by arches when passing under walls.

The course of the private outfall sewer from the dwelling should be as direct as possible, and where one line cannot be adopted, it should consist of straight lines from angle to angle, at each of which an inspection and ventilation shaft, or covered sump, should be provided. Care should be taken, by the use of concrete or by other expedients, to prevent the sinking of any of the pipes in infirm soils and to sustain true line of continuity. A faulty sewer close to a dwelling is always to be dreaded from the

FIG. 6.



circumstance that the inner warmth of the dwelling will draw in any noxious gas existing in the sewer through the fault itself. The union of the private communicating sewers with the common or outfall sewer should be effected by a curved junction (*see* Fig. 6), so that the sewage should be delivered to the common sewer in the direction of the main current, and where possible at a sufficient height above the level of the ordinary flow of sewage, so as to prevent the sewage being "backed" or forced into them from the common sewer.

(3.) *Inclination and Velocity.*—It should be laid with an inclination which will secure for its contents a velocity of not less than three feet, and not more than ten feet per second wherever those limits can be regarded. Where a less velocity than three feet per second can only be obtained, more than ordinary care must be exercised to secure the best formed and best glazed pipes, in order to prevent the adhesion of solid matter to the sides of the pipes. Where it is not possible to procure the desired velocity for the ordinary flow of the sewage to be discharged, an effective and special means of flushing must be provided, which should be automatic in its action if possible.

(4.) *Size.*—It need not exceed six inches in diameter, except in very large establishments or institutions containing a large number of inmates, when nine-inch pipes, or pipes of an intermediate size, may better answer the purpose.

The following table, giving the velocity and discharge of different sized sewers laid with different inclinations and running full will be suggestively useful :—

| Diameter of pipe. Inches. | Velocity, 3 ft. per second. | | Velocity, 4½ ft. per second. | | Velocity, 6 ft. per second. | | Velocity, 9 ft. per second. | |
|---|---|---|---|---|---|---|---|---|
| | Fall. | Discharge per minute. | Fall. | Discharge per minute. | Fall. | Discharge per minute. | Fall. | Discharge per minute. |
| | | gallons. | | gallons. | | gallons. | | gallons. |
| 3 | 1 in 69 | 54 | 1 in 30·4 | 81·0 | 1 in 17·2 | 108 | 1 in 7·6 | 162 |
| 4 | 1 in 92 | 96 | 1 in 40·8 | 144·0 | 1 in 23·0 | 192 | 1 in 10·2 | 288 |
| 6 | 1 in 138 | 216 | 1 in 61·2 | 324·0 | 1 in 34·5 | 432 | 1 in 15·3 | 648 |
| 9 | 1 in 207 | 495 | 1 in 92·0 | 742·5 | 1 in 51·7 | 990 | 1 in 23·0 | 1,485 |
| 12 | 1 in 276 | 876 | 1 in 122·4 | 1,314·0 | 1 in 69·0 | 1,752 | 1 in 30·6 | 2,628 |

The above table will help to fix the size of pipes used for dwellings, the engineer making such deduction or allowance as

the special conditions of each case may demand. In applying the table practically, reference should, of course, be had to the maximum rate of outflow which may take place at any time of the day. It will be observed that the number of gallons which the different pipes are capable of discharging in a minute, when running full at the different inclinations specified, will often exceed the total quantity of sewage to be discharged from a dwelling in the whole of the day, and yet it may be desirable to use a pipe with such excessive capabilities of discharge.

(5.) *Inspection Shafts.*—Where it is of considerable length, and follows a favourable course, inspection shafts will be found useful for observing the flow of sewage, and for ventilating the sewer itself. They may be constructed in brickwork, or of pipes rising to the surface and fitted with cast iron covers. Care is necessary in placing these shafts, so as to avoid the objection of an escape of gases in frequented places, or they may become a nuisance instead of a benefit.

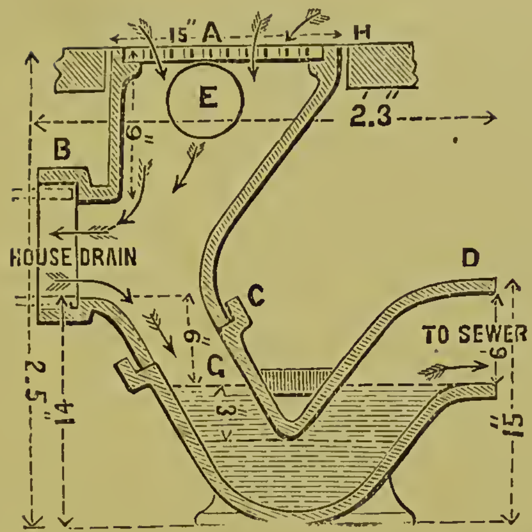
(6.) *Disconnection from Public Sewer or Cesspool.*—In the course of the outfall sewer below its lowest junction with the dwelling, a chamber for its ventilation fitted with proper trapped arrangement for disconnection from the public or common sewer (if there be one) or from any "cesspool or other like receptacle" into which the sewage may be discharged, should be constructed in order to prevent the uprising of the sewer gas from beyond. Several attempts have been made to devise a chamber generally applicable which shall effect this disconnection, but the attendant circumstances vary so much in different cases that no one shape of chamber can be universally adopted, though the object of all is to exclude outside gases and effluvium by the best description of trap, and to admit air on the dwelling side of it, which shall pass through the outfall sewer to find outlet by soil pipe, or by a separate ventilating pipe fixed for the purpose at its head.

Messrs. Doulton show in their catalogue an air chamber manufactured by them for Dr. Corfield, Professor of Hygiene at the Parkes Museum, and Mr. Judge, Curator of the same Museum. The plan, however, though it aims at a good object, presents several features of an objectionable character.

For pipe sewers of various sizes, where sufficient fall is available, Mr. Hellyer, of Newcastle Street, Strand, has invented a good means of disconnection (*see* Fig. 7). Here, as may be judged from the illustration, the disconnection is satisfactorily effected by means of a watertight seal of at least 3 inches deep, and the discharge from the "house sewer" above is made to fall with a *vertical* pressure upon the water in the trap below which is thus with more certainty driven out by the periodical flushes from above, than with flatter and therefore more sluggish syphon traps.

In areas or elsewhere where a grated covering to the chamber

FIG. 7.




would be objectionable,—inasmuch as effluvium might rise from it, and under certain conditions would find its way by the lower windows into the house,—an air-tight lid or stone cover should take the place of the grating, whilst the air should be admitted by a pipe rising from the chamber up the area wall, or by some other suitable means, to which may be attached a self-acting light flap hung on Dr. Arnott's principle to admit air from without, and prevent any escape from within. Mr. Dyer, of Camden Town, has applied this arrangement very skilfully. It is asserted, however, by some experts that if there be a ventilating pipe to the sewer, and that pipe is provided with an exhaust cowl, no such artificial method of preventing the escape of air at the base is necessary; but I am unable to concur with this assertion.

XXXVI.—TRAPS.—Before bringing under notice the different classes of appliances with which it is necessary that all persons aiming at healthy homes should be acquainted, it should be understood that the specimens figured in the following pages are intended rather to illustrate different requirements, and the means by which they may be met, than to convey any preference of particular designs. The objects shown at the Museum of Hygiene, and at the country meetings of the Sanitary Institute of Great Britain, as well as at other occasional exhibitions, show very clearly the progress made in the mechanical branches of sanitary science, and if the opinions of the judges were published to justify the award of prizes or medals then given, they would be of great public utility, as they would indicate not only the special advantages the selected appliances possess, but they would show the progress made in each class of exhibits. This course has been most usefully adopted by the Royal Agricultural Society of England at their shows. As the practice now prevails, the judges upon whose dictum medals are granted,

and awards given in the name of the Sanitary Institute and other public associations, have been generally personally interested either as inventors themselves or as professional advisers, and their judgments therefore carry little weight. They have not given the public the benefit of the reason upon which their preferences have been based, and the consequence has been that selected appliances stamped with such approval have hitherto been regarded as simply commanding the individual preference of judges who are themselves competitors for public support.

Traps used in the *external* sewerage of dwellings may be thus divided: (1) soil-pipe traps; (2) sink traps; and (3) yard or road traps.

(1.) *Soil Pipe Traps.*—Some sanitarians consider it desirable to disconnect the soil pipes of water-closets from the outfall sewer of the dwelling by means of traps, which afford ventilation at their base. There is, however, so much probability of an evil or annoyance arising sooner or later from the adoption of this plan, that in spite of the arguments used in its favour, it would seem better in most cases not to break the continuity of the soil pipe directly at its base, but to trust entirely to well devised trapping in the closet with proper ventilation above of both the soil pipe and the closet trap. With the usual disconnecting chamber in an unobjectionable position with its inlet of fresh air, the escape of gas from the main sewer into the dwelling is prevented, and the water in the closet pan cannot become fœtid.

Where, however, the disconnection of the soil pipe directly at its base is insisted upon, either of the traps figured 8 and 9 are applicable.

FIG. 8.

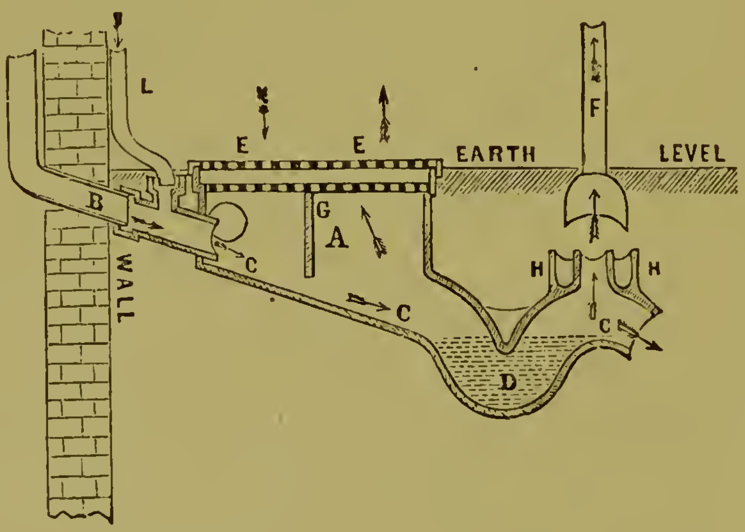



Fig. 8 is manufactured by Messrs. Potts and Co., of Handsworth, near Birmingham, and thus described by the inventors :—

*A* is an air-chamber 2 ft. 6 in. or 3 ft. long. *B* is the soil pipe from closet. *C C C* shows the course of soil through trap to sewer. *D* is an ordinary water valve or syphon. *E E* is an open grating raised two or three inches above the ground level, having a second grating or tray below it, on which charcoal or other disinfectants may be placed. *F* is a pipe reaching to the roof, about two inches diameter; this pipe is so fitted to the trap that it can, if desired, be luted with sand or plaster, so as to admit of its being readily raised to give access to the pipes for clearing purposes. *H H* lower portion of joint for pipe *F*, showing opening to trap. *G* is a division plate or diaphragm, dividing the air-chamber into two parts; it assists in directing the gas out of the chamber *A*, and acts so as to create a current of air through the trap. *L* is a pipe joining the soil pipe by a junction before it enters the air-chamber.

The trap should, where practicable, be placed parallel to the wall of the house, and the soil pipe should be so arranged as to enter into the air-chamber as shown in the wood-cut; this can be effected by turning the end of the soil pipe, even when the sewer follows a course at right angles to the wall of the house. It does not interfere with the action of the trap if the soil pipe enters the air chamber at the side, but it is not so good for flushing purposes.

Housemaid's sink or waste-water pipes may enter at the side, and where more than one closet is connected with the trap, the connection may be made at the sides. The pipe so connected should be obliquely inclined towards the bottom of the trap and sewer. It is imperatively necessary that the grating E E should stand a little above the ground level and be open to the air; it matters not how much, provided it be not less than 2 or 3 inches, so as to prevent the admission of gravel or sand with surface waters. In cases where it has to be fixed to pipes much below the ground line, it is necessary to build up the sides of the air-chamber until they reach 2 or 3 inches above the surface. This is readily done by slabs of slate, stone, or brick (the former are best) on which the grids may be placed. It is absolutely necessary to leave the top of the air-chamber open to the air, whatever may be the depth at which it is fixed.

FIG. 9.

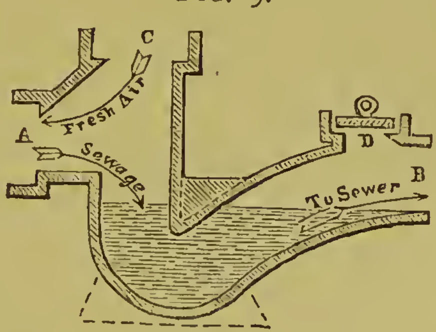


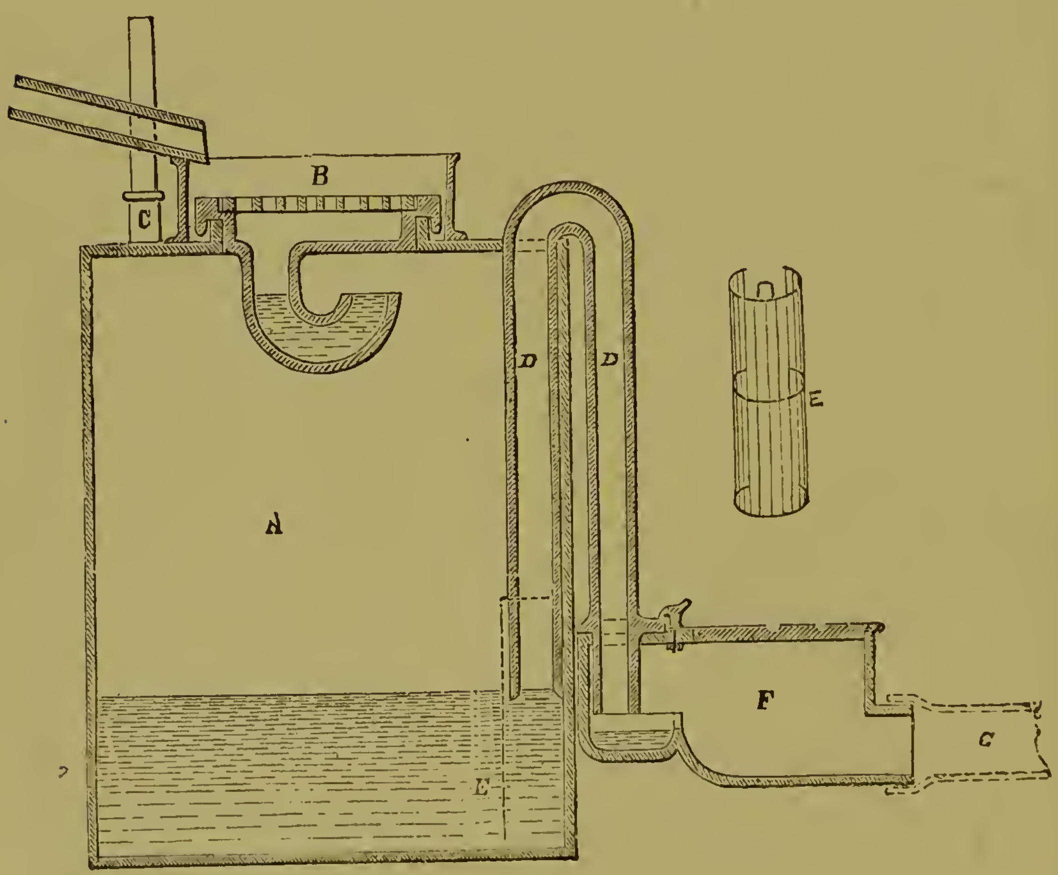

Fig. 9 shows one of Buchan's (of Renfrew Street, Glasgow) traps.

Mr. Buchan states that an advantage is gained by the liquid being made to fall over a sharp edge from A into the trap, whereby any fœcal matter descending from A into the outfall sewer will be broken up and washed forward. A means is provided at C for the admission of fresh air into the soil pipe, and for clearing the trap at D, if any stoppage occurs.

(2.) *Sink Traps.*—It is now universally recognized that all pipes

discharging the liquid refuse of the dwelling from either scullery, butler's pantry, or housemaid's room, and where possible from the lavatory or bath-room, should be disconnected from the outfall sewer, and that this should be done by a break *outside* the dwelling. Numerous traps have been invented to secure this object, which at a small cost effectually prevent the influx of effluvium. In some the liquid as it is discharged is made to fall *upon* the grated covering of the trap, in order that those coarser materials which are often thrown down sinks, and which, if admitted into the sewer, would help to choke it, may, as already stated, be intercepted and removed by hand, while in others the liquid enters the trap *below* the grating. The first trap which should be noticed is Rogers Field's flush tank, which not only does what any other trap does but by automatic discharge when the tank is full, serves to flush the sewer into which it discharges. By its adoption, in fact, not only is disconnection thoroughly effected, but the liquid relieved of its solid matter, partly by the interception of the grating and partly by collection in the tank, discharges itself in sufficient quantity to flush the outfall sewer. The collected solid matter is removed separately by hand. Fig. 10 shows this apparatus which consists

FIG. 10.

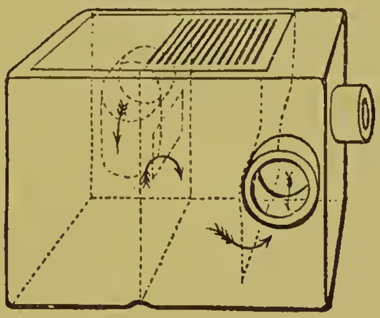


of a cylindrical watertight iron or stoneware tank A. This tank has a trapped inlet B (which also forms a movable cover to give access to the interior of the tank), and a socket C for a ventilating pipe. The outlet consists of a syphon D, so arranged that no discharge takes place till the tank is completely filled with liquid, when the syphon is brought into action and the contents are immediately discharged. The inner end of the syphon is protected by a strainer E, to hold back grease, &c., and the outer end enters a discharging trough F, which is made to turn round so that its mouth may be directed as required to connect the tank with the line of outlet pipes (G). This trough has a cover which can be removed to give access for cleaning. In this contrivance the liquid refuse from the house sinks is discharged on to the grating.

Up to this time Field's flush tank has the preference as an automatic intercepter of solid matter and flusher of the outfall sewers of dwellings, but there are other devices in which floating outlets and tip-over boxes are the distinguishing feature which will share with it before long the popularity it now deservedly enjoys. Messrs. Stone, of Deptford, are introducing an "automatic flusher."

The number of traps which receive the outflow from a dwelling, either above or under a grating, and prevent the passage inwards of sewer air are very numerous, some being double sealed and some single sealed.

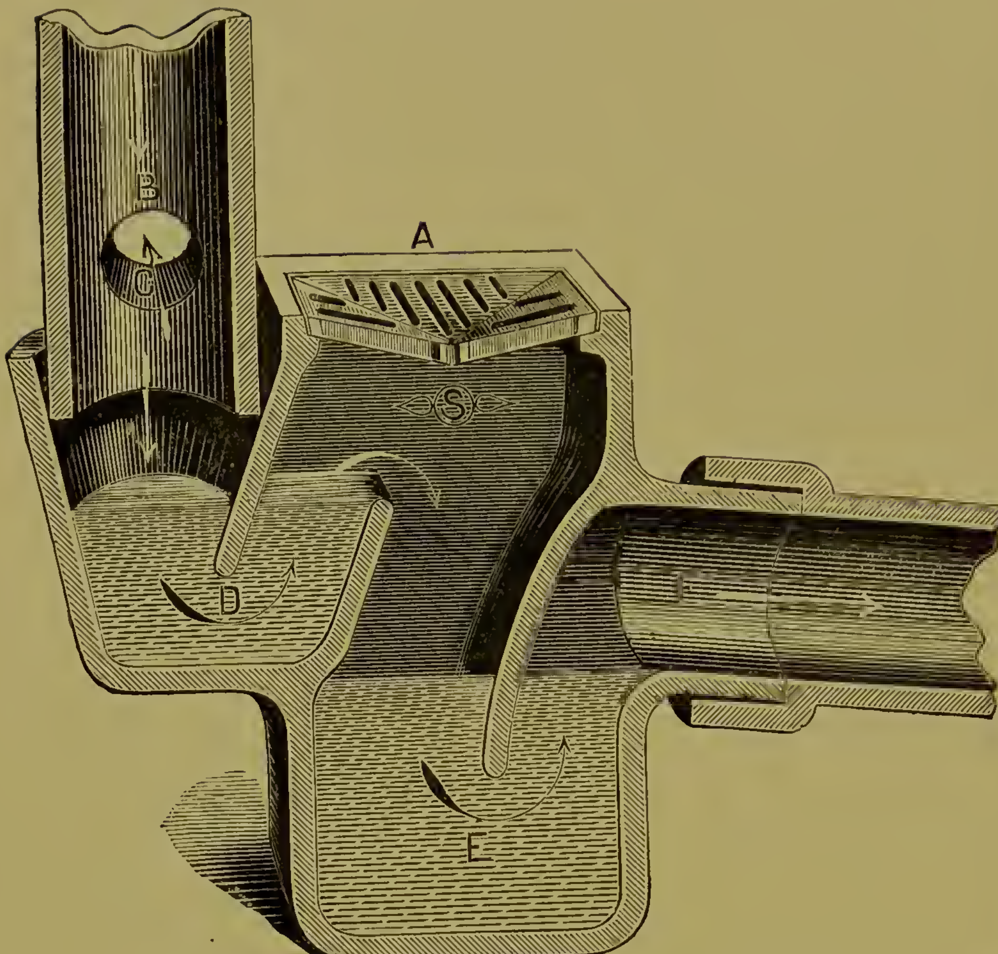
FIG. 11



*Double Sealed Traps.*—In Mansergh's trap, Fig. 11, it will be observed that there are two water seals, so arranged that an open communication to the air is provided by a grating between them. When the pressure in the sewer is sufficient to force the gas through the first or lower seal it will escape through the grating rather than through the second seal into the house. This trap also serves as a grease trap, but the emptying of the container not being automatic nor complete, it requires constant attention to keep it in free action, which is not the case when a syphon is used.

Fig. 12, on a larger scale, shows, a good stoneware disconnecting trap manufactured by Messrs. Stidder and Co., of Southwark

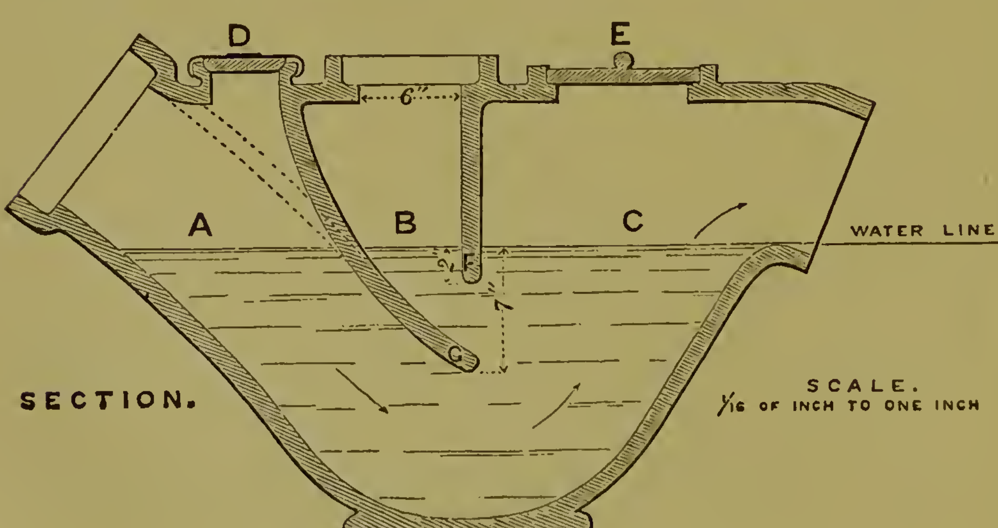
FIG. 12.




Bridge Road, which like the last is doubly trapped and doubly ventilated.

The same may be said of the excellent air trap of Messrs. Stiff, of Lambeth, Fig. 13.

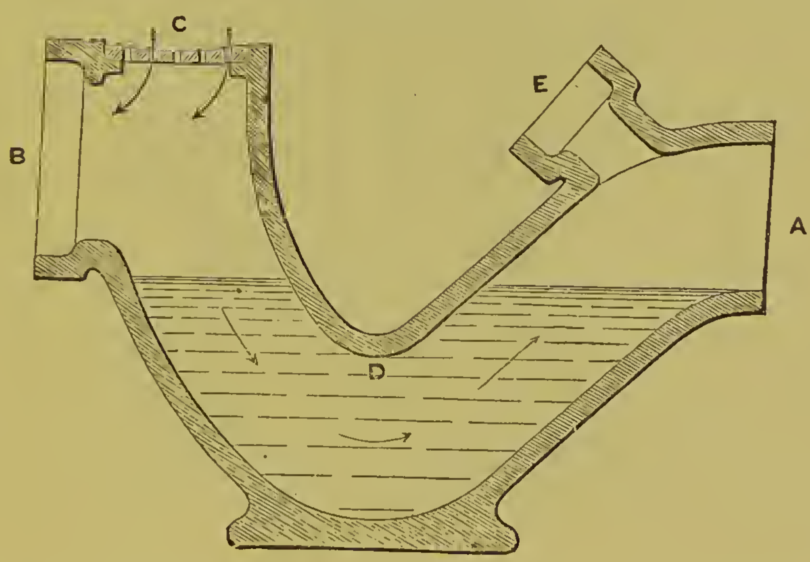
FIG. 13.



The air from the sewer is intercepted by means of two dips or water seals F and G, between which a means of ventilation is provided which may be carried up the walls of the house. Under ordinary circumstances the foul air will be stopped at the chamber C, but should the pressure be strong enough to force the trap at F, the sewer gas will at once escape through the chamber B into the ventilating pipe. The second and stronger trap at G is said to effectually exclude all poisonous gases from chamber A, which forms the only avenue to the house. The diaphragm G is so constructed that the sewage from the house is discharged directly into the trapped chamber C, beyond the point of communication with the open air. By this arrangement the necessary ventilation of the trap is effected, with the minimum of contamination to the surrounding atmosphere. D and E are closely covered apertures for cleansing the trap, which is usually made with the latter opening only, but the aperture D is now generally added. When the house sewer is deep, a pipe should be conducted vertically from the opening E to about 9 inches below the ground level, then carefully closed with the disc plate and covered with earth. By means of a long-handled ladle any subsequent obstruction in the trap may soon be removed without trouble or expense.

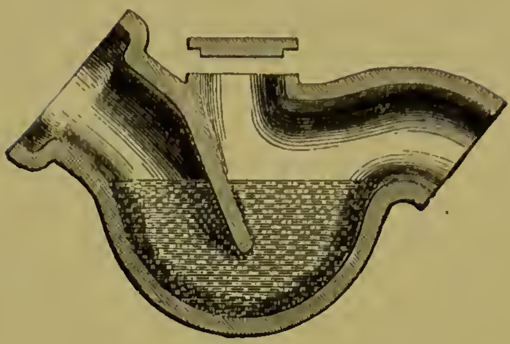
*Single Sealed Traps.*—Messrs. Stiff manufacture a single sealed trap (Fig. 14) called the Weaver ventilating sewer air trap.

FIG. 14.




They also make that useful trap known as the Redhill trap, Fig. 15.

FIG. 15.

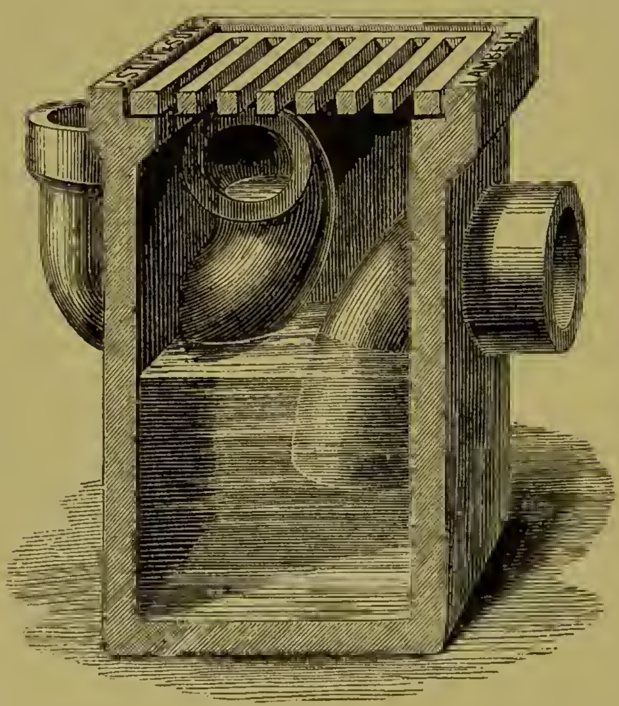


This trap and the Bavin dip-trap, which is well known, are very much of the same character.

The newly-registered Wetherley trap, which is more of the nature of a double than a single sealed trap, should not be omitted from notice, as it would seem to be capable of acting well, not only as a disconnecter, but as an intercepter of grease if properly attended to.

Fig. 16 shows this trap.

FIG. 16.

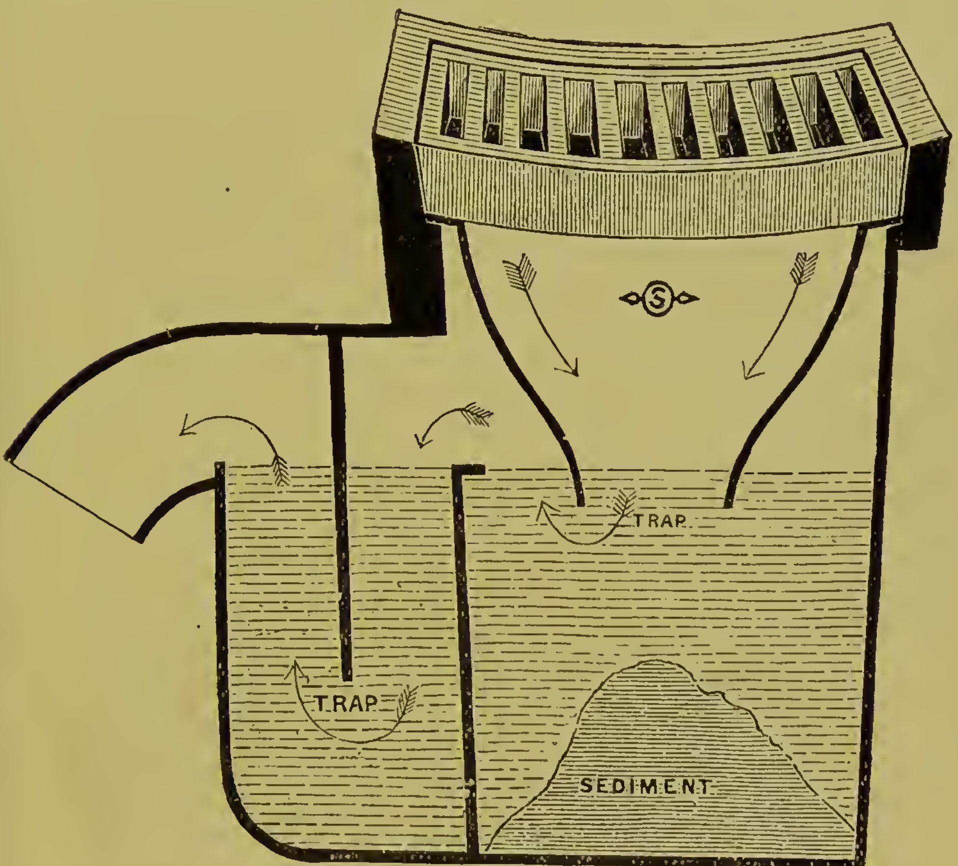


(3.) *Yard and Road Traps for intercepting Solid Matter or Detritus.*—There are numerous traps made by different makers to intercept the solid matter washed off the impervious surfaces of yards, roads, &c., and at the same time prevent any uprising gas when connected with sewers.

Brickwork or cast-iron chambers, with a deflected pipe on the the lower side, are generally used in preference to earthenware traps, on account of the heavy traffic which might pass over and break them.

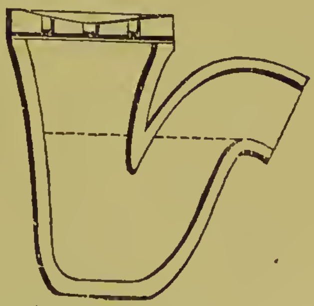
"Stidder's Improved Iron Yard Gully," Fig. 17, can be safely adopted in any case. Here the solid matter, intercepted in the first division, can be easily removed and ready access obtained to the whole of the trap.

FIG. 17.




Doulton's Earthenware Yard and Road Trap, Fig. 18, with which the last (iron) trap may be compared, serves to illustrate a cheap description of trap that may be found suitable where traffic of a heavy character may not exist, or where relief from surface water is required by the side of carriage drives, &c. It should be understood, however, that all these traps *require frequent emptying*, and that in continued dry weather they require to be furnished with water, or stench escaping from the sewer will be perceptible.

FIG. 18.



To prevent gases generated in a public sewer or cesspool from

passing up the private outfall sewer, light flaps may sometimes be favourably introduced at the junction of the one with the other. This arrangement, however, can only be effected when the public sewer is constructed of brickwork, and when an increased fall can be given to the private sewer just above the junction. These appliances are not to be generally recommended.

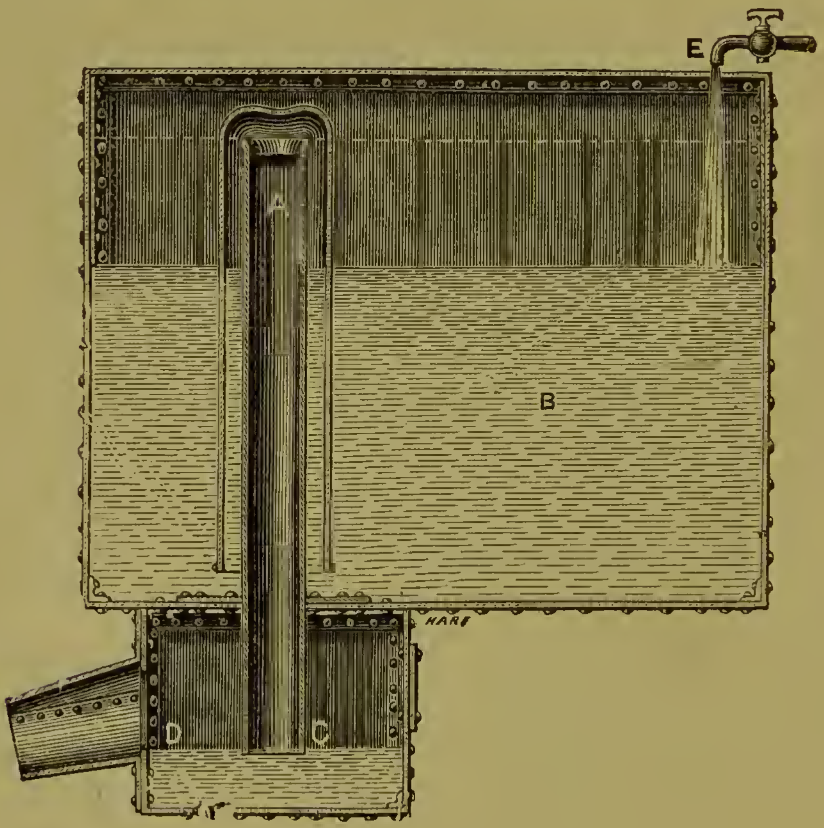
Stress has already been laid on the advantage of disconnection, and the necessity of ventilating the soil pipe of the water-closets and the traps of sinks communicating with the outfall sewers of all dwellings, and it should be here repeated that with this arrangement properly effected safety from sewer gas will be assured.

XXXVII.—Chambers for collecting Surface or other Water for flushing Sewers.—Under the head of sink traps reference has been specially made to "Field's Flush Tank," which performs the double function of disconnection and flushing.

For the latter object, Mr. Field has brought into use his patent annular syphon, which is admirably adapted for the purpose. When fixed in a chamber, as in Fig. 19, where it can be economically supplied with liquid in any quantity, it is most useful.

His agents, Messrs. Scott and Read, thus describe the arrangement adopted by Mr. Field.

Fig. 19.



"The chamber is emptied by means of a self-acting annular syphon, which is put in action by an extremely small flow of water, so that a large tank may be fed, for instance, by the constant flow from a small water tap or drain which takes a day or two to fill it, and yet the tank will empty itself automatically, in the course of a few minutes, as soon as it is full.

"The working of this apparatus is very simple, and it is almost an impossibily for it to get out of order.

"The syphon (A) is built into a tank (B). The longer limb of syphon just dips about one-eighth of an inch into water below the tank at (C) which is kept at its proper level by a weir (D).

"The action is as follows :—When the water fed from inlet or tap (E) rises to the top of the longer limb of the syphon shown by dotted line, instead of running down the sides, it is guided by a lip, and is caused to descend clear of the sides. By this means a quantity of air is displaced, gradually forming a vacuum in the discharging limb, and thereby starting the syphon, which empties the tank with enormous rapidity."

Mr. Shone, of Wrexham, aims at precisely the same object as Mr. Field, in what he has designated his "House Hydraulic Sewage Ejector"* (Fig. 20), and claims for his invention both originality and superiority. Its arrangement is very similar to that which has been already applied in the form of the "sewage regulator" with its float or syphon outlet. Its chief characteristic is the application of a tumbling box so fixed on a pivot as to capsize suddenly when it is filled, thus starting a syphon which empties the flushing tank. The illustration will convey to the reader pretty clearly the action of the invention, though it should be explained that this tumbling-box, being made to receive the outflow from the dwelling, must be constantly in action, even though the tank into which the contents are thrown be not filled. This, although not a great objection, does not apply to either Mr. Field's flush tank or to Messrs. Stones' automatic flusher. In this last invention it is so arranged that the tumbling-box only comes into action when the tank is full, and that it throws its contents into the syphon precisely at the time it is intended that the tank should be emptied. Thus the chances of derangement are greatly reduced.

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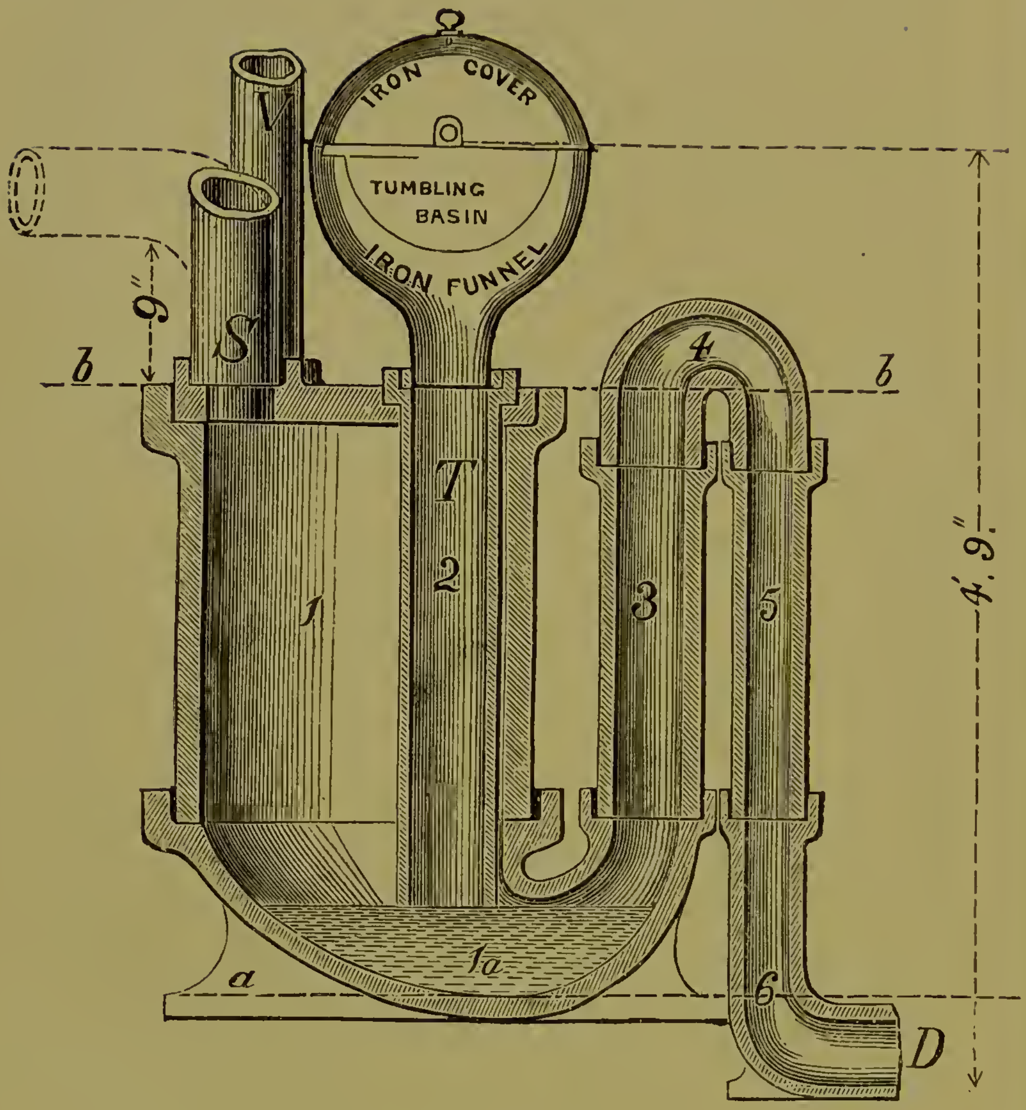
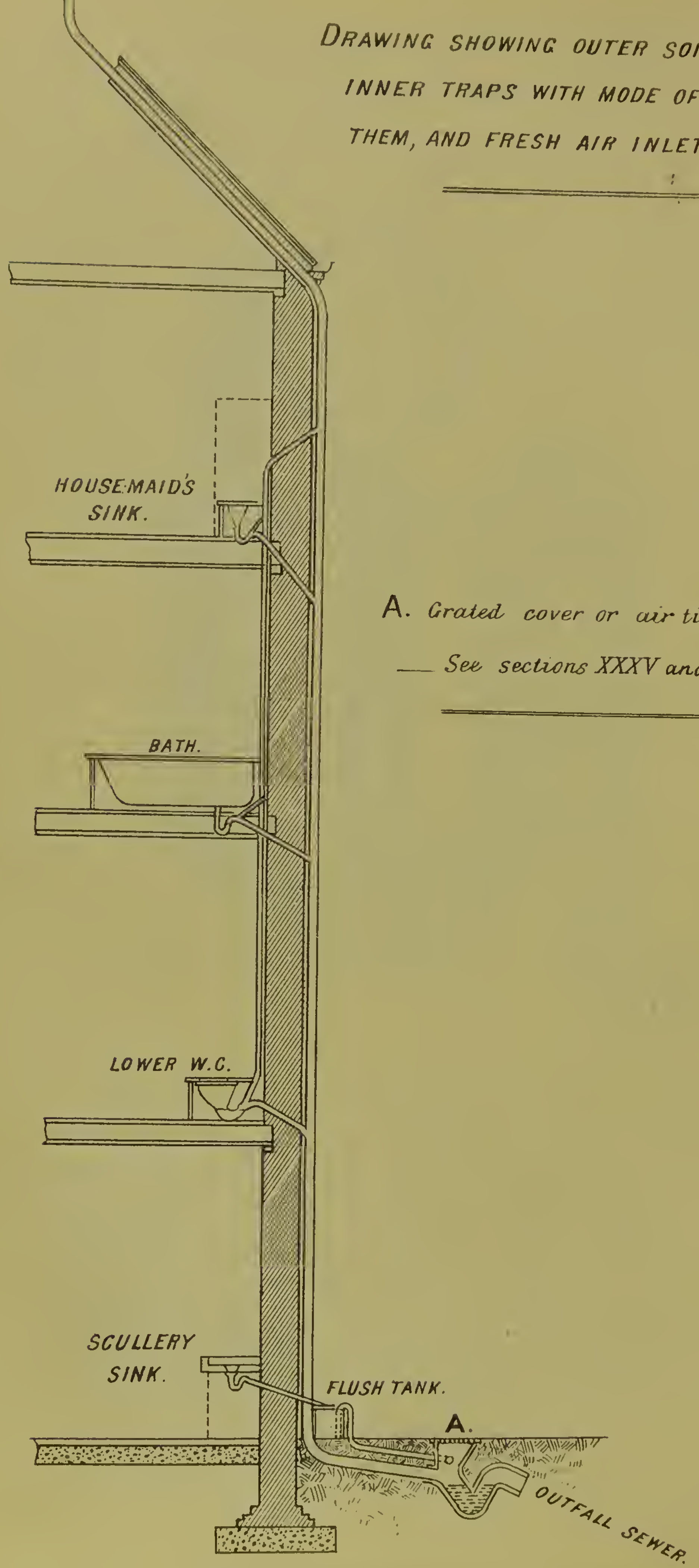
* Mr. Shone has invented for the sewerage of towns a contrivance which he calls the Pneumatic Ejector, in which is displayed much ingenuity, and which will be found of advantage in some districts. The writer has had no experience of the invention, but he believes it is in successful action at Eastbourne, in Sussex.

FIG. 20.




If placed outside the wall of the house it will be seen that the tumbling basin may be advantageously acted on by the sink waste pipe, or by any other refuse supply, without one drop of clean water being used and wasted. The inventor states that the tumbling basin, besides being necessary to start the action of the syphon ejector, is also a valuable sanitary adjunct to house drainage, for it dispenses with the use of a grease trap. In many instances the fatty waste liquids of a house trap congeal or freeze and gradually choke up the house drain, whereas falling into the tumbling basin (or direct into the ejector tank), though they should congeal or freeze before the basin is filled, the moment the basin topples over its sudden jerky action throws the

DRAWING SHOWING OUTER SOIL PIPE AND INNER TRAPS WITH MODE OF VENTILATING THEM, AND FRESH AIR INLET AT BASE.




A. *Grated cover or air tight lid & pipe — See sections XXXV and XXXVI.* —

Harrison & Sons, Lith. St Martins Lane, W.C.

whole charge into the ejector, and this latter in its turn passes it speedily into the public sewer. It will be noticed that there is a most perfect disconnection between house and sewer.

Another very simple mode of utilising the rainfall, as discharged from the roofs of houses, consists in fixing to the bottom of a down pipe an ordinary tank or cistern fitted with a syphon, which comes into action whenever the quantity of water discharged from the roof or elsewhere has filled the tank to a height above the crown of the syphon.

XXXVIII. Ventilation of the Outfall Sewer and its Branches, including Soil Pipes and the Traps Connected therewith.—The required ventilation of the outfall sewer and its various branches,—*i.e.*, the expulsion of foul air into the open atmosphere, and the admission of fresh air to take its place—is usually effected by ventilating pipes rising from the various points of sewage collection up the outside walls to a position in which they will cause no nuisance. (*See* opposite drawing). The proper ventilation of the soil-pipes of water-closets and any other branch sewers rising up the houses and discharging offensive liquid can only be secured by carrying them up to and *above* the roof, and by admitting fresh air below where it can be favourably done. It is hardly necessary to observe that where water closets are in the centre of the house, as they frequently are in populous towns, involving the placing of the soil pipe inside, instead of outside the house, increased care is necessary to free the dwelling from the escape of effluvium. Ventilating pipes should not be less than four inches in diameter. The *down pipes* for the discharge of rain water from roofs should be avoided as ventilators, though in certain cases they may be used without objection.

It has been advanced that in order to secure a constant "up-draught" to the ventilating pipes attached to dwellings that hoods or cowls should be placed on the top of them, which by special construction shall draw out the contents of the pipe and induce an upward current from below. There are several inventions aiming at this object which will be described when speaking of the ventilation of the dwelling, but all such arrangements are only to be recommended when a proper circulation of air cannot be secured by more simple means.

XXXIX. Mode of ascertaining the direction of the current of Air in Sewers or Pipes.—One of the first duties of an inspector into the sanitary condition of dwellings is to try and ascertain with precision whether the current of air (sewer gas) in the sewer is travelling in a direction to find outlet by faulty traps *within* the house or otherwise.

To do this several instruments have been devised, which can

be placed within pipes, but none have yet been sufficiently positive in their action to indicate the facts quite satisfactorily. The air meters of Casella, and other makers, are instruments which may sometimes be used with advantage, and full instructions for their use are always supplied with them.

XL.—Modes of determining whether Stoppages exist in the House Sewer and its Tributaries, and whether any Gases or Effluvia from Sewers penetrate into the Dwelling.—The periodical or occasional examination and testing of the sanitary arrangements of the dwelling is obviously a matter of necessity, and its occupants should themselves be able to undertake or direct this investigation.

To determine whether a stoppage exists in any of the pipes, the house outfall sewer should be watched at its "disconnecting chamber," or, in cases where there is none, it must be opened at a point immediately below where it leaves the house. Water should then be poured down each branch separately, when the observer, watching at the point stated, will be able to discover the position of any stoppage. By noticing, too, the time the water takes to reach the opening, where no stoppage is discovered, its velocity may be approximately judged, and a fairly accurate opinion formed as to the state of the sewer and its tributaries.

To determine whether sewer gas enters the dwelling is equally essential. By placing a flame over each of the sink traps throughout the house it will be seen whether there is any draught from the house sewer into the dwelling, and by pouring either ether or oil of peppermint down the soil pipe any leakage from the pipes, or failure in trapping, which otherwise would not be ascertained by the nose, will be discovered by the fumes being easily perceptible in proximity to where the leakage exists. The fumes of tobacco or sulphur will also act as a test in a similar manner, and may be applied at the "disconnecting chamber," care being taken to stop up the opening of the sewer below, with either clay or some covering to render the passage of the fumes *down*, instead of *up*, the sewer a matter of impossibility.

## CONTENTS OF CHAPTER V.

### INTERNAL SEWERAGE.



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## CHAPTER V.

XLI.—Water-Closets and the Appliances connected with them, including Water Waste Preventers.—With very few exceptions the excremental refuse of superior dwellings in this country is discharged through the medium of water-closets, the only exceptions being those comparatively few cases where earth-closets have taken their place, and those in which neither earth nor water-closets exist *within* the dwelling, and the inmates therefore follow the old but waning custom of using *external* closets of some kind or another.

Two important objects should be aimed at wherever water-closets are used. (1.) They should be so placed that no objectionable smell shall find its way into the other parts of the dwelling when they are used. (2.) Their machinery should be so arranged that no gases from either sewer, soil pipe, or trap shall escape inwards.

To effect the first-named object, all water-closets should be constructed against external walls with a means of direct open air ventilation—not necessarily by open windows—and there should be in addition, wherever it can be so arranged, a lobby, ante-room, or passage provided with a like means of ventilation, and a second door cutting this lobby or apartment off from the interior of the dwelling. But it very often happens that the effect of this arrangement when imperfectly carried out is far from satisfactory, inasmuch as the colder air admitted from without drives forward the warmer odour which the lobby is intended to arrest.

In many instances water-closets constructed in the centre of dwellings (as in the Metropolis and other towns) are free from

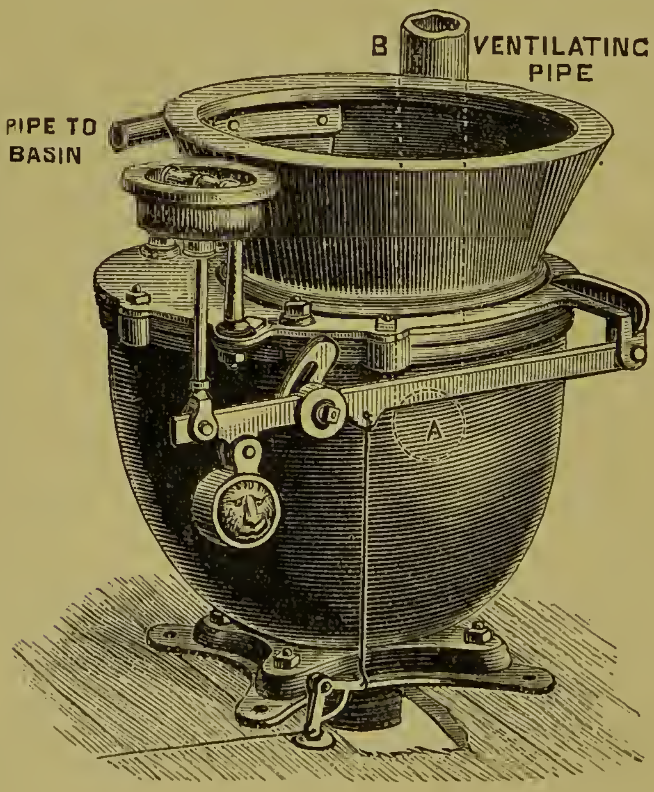
these objections owing to the little difference in temperature of the staircase upon which they are generally placed and the closets themselves, whereby the effluvium is dissipated without any very sensible effect. This arrangement, however, is not to be recommended, as under unfavourable circumstances it is extremely objectionable and sometimes dangerous.

To prevent the escape of gases from the soil pipe inwards most careful trapping in every case should be insisted on, associated with a perfect means of ventilating the soil pipe (by extending it up to and above the roof, and admitting air below), and also by a branch pipe rising up into the soil pipe, or into a separate ventilating pipe from the trap beneath the closet basin.

Though it is a general practice, in houses of all descriptions, to use water-closets as sinks for housemaid's refuse, there is no custom more objectionable in the case of valve closets, not only because it is a filthy one, but because it is also conducive to derangement of the closets themselves. In many instances, however, it is not possible to have a separate housemaid's sink, in which case valve closets should give place to valveless ones, and the ordinary wooden seat should lift as a lid on hinges to cover a false seat of lead, forming an "overall," upon which the housemaid may throw her slops without creating annoyance.

With respect to the precise character of water-closet to be

FIG. 21.



adopted much care in selection is needed, not only because special circumstances should always be taken into consideration, but because a great number of those closets generally known to the public are imperfect in their action. Some collect within them a portion of the foul matter it is their purpose to discharge, and thus partake of the character of small cesspools within the dwelling. This is particularly the case with the closet known as the "Pan Closet" (*see* Fig. 21) which, although it is still adopted to a very large extent throughout the country, should always be looked upon with suspicion owing to the large cavity which exists between the basin and the trap. This cavity in time must become foul, and, noxious gases being generated, they escape directly into the house whenever the closet is used, or pass indirectly through the water by absorption.

It is generally associated with the often condemned D trap, which is not illustrated in this treatise because its defects are well known, and because there are so many simpler varieties of traps in use, which are free from objections of any kind.

For the sake of simplicity water-closets may be classified as either "valve closets" or "valveless closets," which being subject to many modifications partake of a great variety of character.

It should be understood that valve closets, though they serve better to put out of sight any excretal matter which may lodge in the container (pan closet), or trap beneath, must necessarily be more liable to derangement than closets without any valves at all. Let the character of the closet be what it may, and let it be as simple as a valveless closet can be, very much will always depend upon the work of the plumber in fixing it, and in bringing to bear each connected appliance with proper effect.

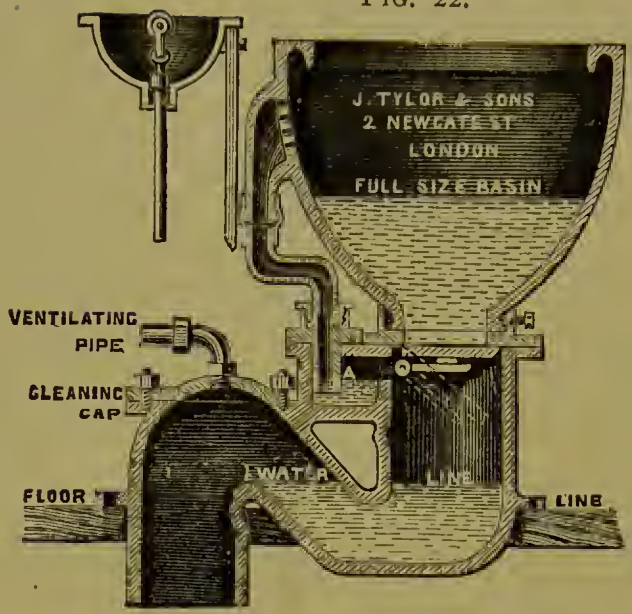
*Valve Closets.*—For dwellings in which expense is not so much an object as perfect action and freedom from objectionable appearance, the valve closets of Tylor and Son of Newgate Street, Jennings of Lambeth, Stidder of Southwark Bridge-road, Underhay of Farringdon Street, and Doulton of Lambeth, may be specified as exemplifying valve arrangements of the first character.

Fig. 22 shows Tylor's Patent Valve Closet with bottom outlet.

It is, as will be noticed, trapped above the floor line, and inspection is rendered easy by means of the "cleaning cap," shown in the illustration. The overflow pipe from the basin is also trapped (*see* A), and the entry of the contents of the basin into this trap is prevented by its being covered by the discharge valve of the basin when open.

This closet is universally acknowledged to be an excellent one, but it should be observed that the only ventilation of the trap is by means of a small pipe on its outer side. This method is neither sufficient nor of much use. It is always much

FIG. 22.

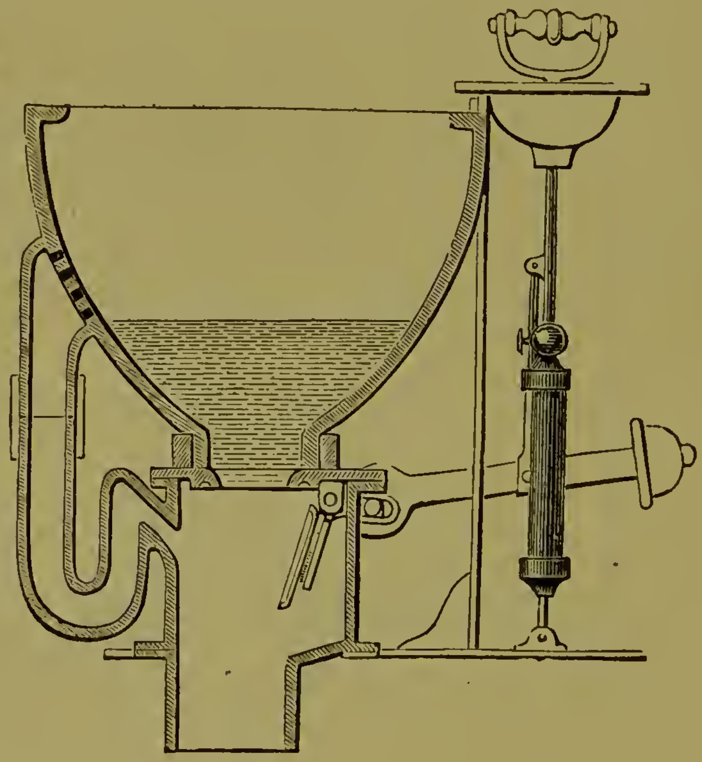



SECTION OF FIGS. $\frac{O\ O}{2,\ 3.}$

more desirable to ventilate the space between the valve and the trap, for, except this is done, it frequently happens that when closets are not in constant use, the solid matter resting in the trap gives off gases, which find their way into the house when the closet is next used.

Fig. 23 represents, by a remarkable drawing, a valve closet with bottom valve manufactured by Underhay, of the Farringdon Road.

FIG. 23.

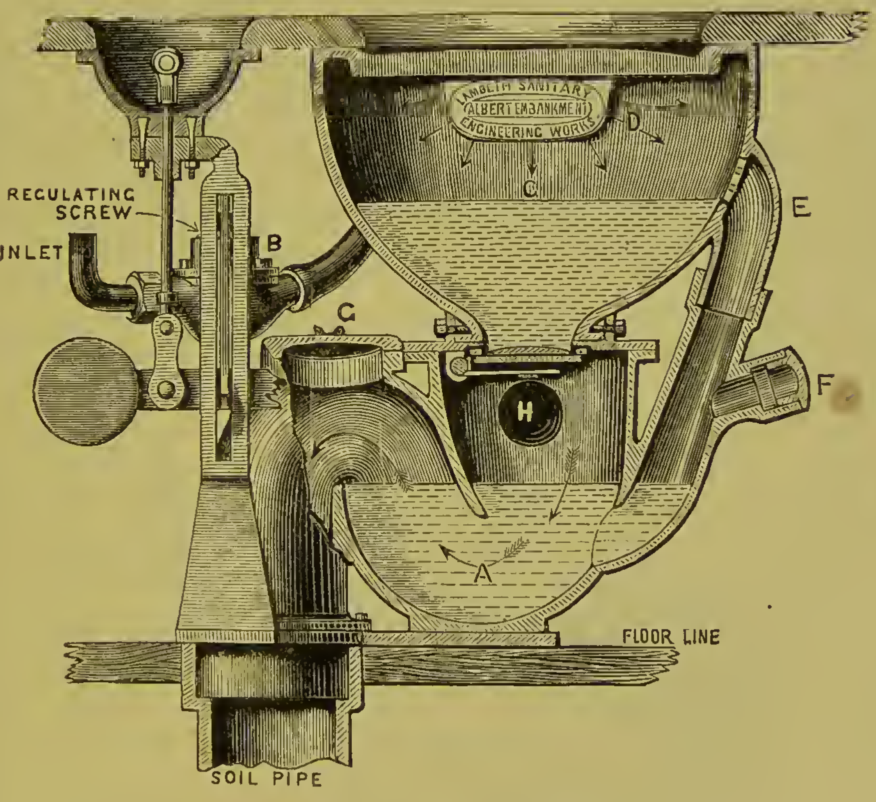


It is very similar to Tylor's closet just described, but its trap is placed below the floor level, and not above as in the previous instance. Some people consider this to be an advantage, inasmuch as a more thorough flush out of the trap is ensured. The same want of ventilation is also experienced as in Tylor's closet, and this to render it a perfectly safe closet should be supplied.

It is shown in connection with one of Underhay's regulators, the action of which is fully explained in a subsequent paragraph.

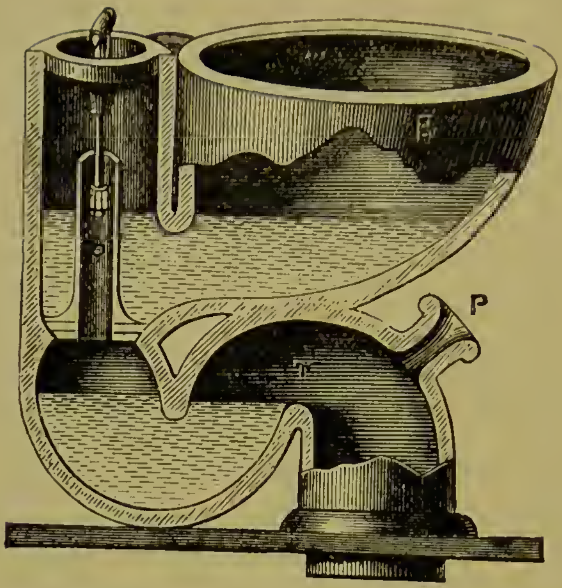
Fig. 24 shows Doulton's best valve closet, which has the advantage of the ventilation wanting in the previous illustrations. In this example the letter G marks the inspection opening with an air-tight cover, affording a ready means of access to the trap in case of obstruction, and H the junction socket at the back of the closet trap for the purpose of carrying a ventilating pipe either into the soil pipe ventilator or into the open air.

FIG. 24.




The closet of Jennings, of Lambeth (Fig. 25), has much to recommend it both for the simplicity of its construction and the compactness of some of its parts, *i.e.*, those shown on the illustration, which consists of a basin and trap in one piece of earthenware.

FIG. 25.

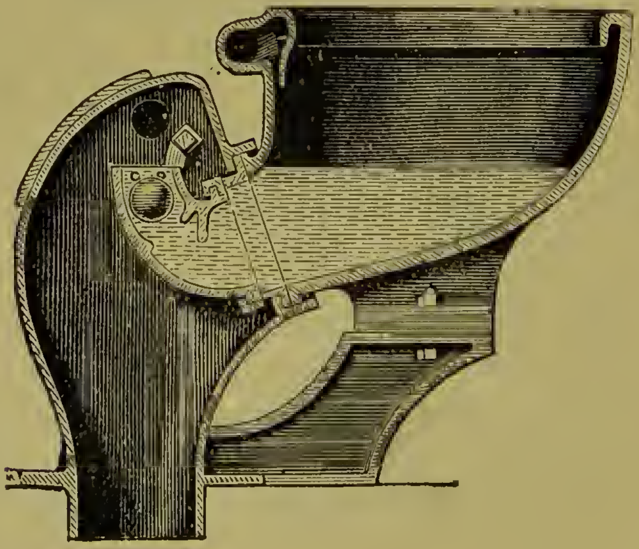



The valve arrangements, however, for supply, discharge, and overflow are not so simple and free from derangement. It should be noticed from the shape of the basin, and the position of the trap, that a very efficacious flush out is secured each time the closet is used. This is a very good example of a side outlet valve closet.

Mr. Jennings has also a Bramah valve closet, which he has brought out with a view to economize water when there is a difficulty in obtaining it in abundance.

Another side outlet closet, manufactured by Messrs. Tylor and Son, is shown by Fig. 26.

FIG. 26.



Here the outlet valve is so constructed as to act as an overflow, thus doing away with the necessity of a separate overflow pipe. The valve is acted on by a pull up arrangement in the usual manner, and to meet those cases where water supply may fail, and the basin be left without water, it is provided with a self-acting arrangement which, though it permits the escape of any overflow, closes the passage against any incoming sewer gas. It is trapped below the floor level.

When the old "pan closet" is still insisted on those manufactured by Messrs. Underhay and Messrs. Doulton are among the best of the kind. Fig. 21, previously illustrated, exemplifies the Lambeth pan closet. It is provided with a strong stoneware container glazed white inside, in which is introduced the socket A for the purpose of ventilating below the pan. By the use of a glazed stoneware container instead of iron Messrs. Doulton maintain that an impervious body is obtained proof against all corrosion, and that thereby the objection to this closet is to a great extent obviated.

*Valveless Closets.*—Many sanitary authorities prefer the valveless or wash-out closet to even the best made valve closet, and there is no doubt that when well manufactured, and well fixed by the plumber, they may be made to answer their purpose perfectly. Their chief characteristic is, as their name implies, that they have no valve arrangements of any kind, and therefore that it is impossible that they should be subject to that derangement and wear which is inseparable from the use of valves. The use of an overflow pipe is in their case considered unnecessary as the several illustrations show. The same remark will apply to "safes" which are always necessary with valve closets to guard against leakage.* In these closets everything may be said to depend on a sufficient flush evenly applied to the basin from a good head of water. They should never be adopted, therefore, where there is a restricted use of water, for with a scarcity of this essential, a deposit will take place in the basin which in itself may become a nuisance.

Being constructed with less mechanism than valve closets, their price is sensibly less, which tells greatly in their favour.

In this class Bostel's (of Brighton) wash-out closet should take the first place.

Fig. 27 is a section of this closet showing the flush of water.

Its action will be understood, without description, from this illustration. To fix the closet so that the water from the flushing rim flows through and round the basin with force to effect a thorough rinse out requires superior plumbing, though this

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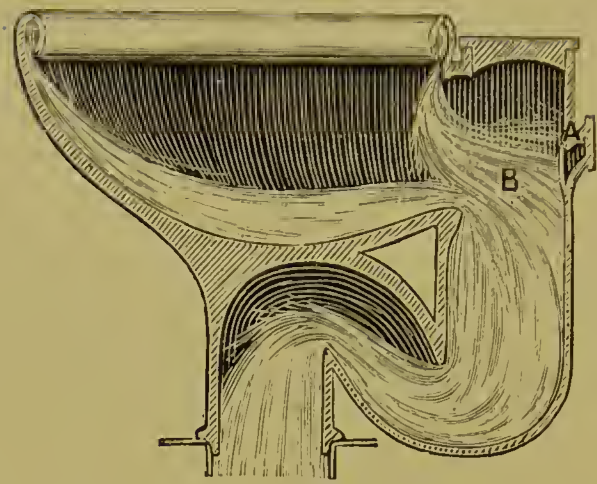
* All "safes," to deserve the name, should be specially ventilated with a discharge pipe directly into the open air, and not as is frequently the case into the soil pipe.

FIG. 27.

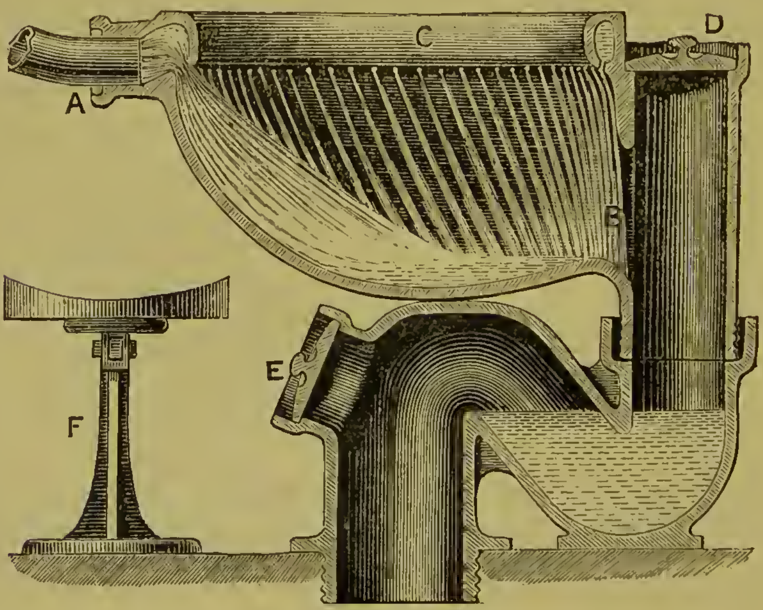



necessity should prove no bar to its adoption. The same may be said of all closets aiming at cleansing the basin by one flush of water as the contents will otherwise cling to it. The depth of the standing water in the basin of any valveless closet should be $1\frac{1}{2}$ inch at least.

In addition to its chief characteristics, the advantage that its maker claims for the Brighton closet are—(1) that it is trapped above the floor line; (2) that there is ready access for clearance; and (3) that in common with all flush out closets it forms a ready and safe means for discharging bedroom slops without valve interference.

Fig. 28 shows Doulton's flush out closet.

FIG. 28.



Here the makers have taken great care in designing the shape of the basin to get the greatest amount of water to remain in it without offering resistance to the outflow. The water enters the basin at the flushing arm A exactly opposite to the discharge opening B, and by this means the whole power is utilized. This closet, unlike Bostel's, is made in two parts.

Over the discharge opening is a plate D which on removal, as in the case of Bostel's closet, gives access to the trap below, and allows of its being cleaned should foreign matter have been thrown into the basin.

A socket E is also provided for inspection or ventilation, and a light iron standard F is sold (when required) on which the basin stands, so that the trap may be turned any way to suit position of soil pipe.

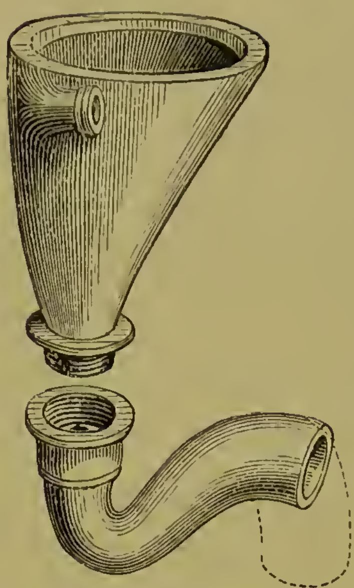
The Lambeth cottage closet, which is rather an elaborate form of "Hopper" closet, is very useful for small dwellings where there is a plentiful supply of water and valve arrangements are not desired. It is designed with special regard to cheapness. Fig. 29 shows this closet.

FIG. 29.


There is but one trap between the soil-pipe and the basin, which, with a copious flush, should render any stoppage or annoyance as unfrequent as is possible with these kinds of closets.

When it is desired to have an outside water-closet for the use of servants, or where the apartment in which the apparatus is fixed is well separated from the remainder of the dwelling,

FIG. 30.



so that no nuisance of any kind can arise; and where there is good command of water, much may be said in favour of the "Hopper" closet (*see* Fig. 30) on account of its cheapness. It consists of a basin and single trap only, the simplicity of which, with its entire absence of valves, affords little chance of derangement from rough usage. The tapering shape is a bar to its universal adoption, but with a plentiful supply of water to overcome stoppage or any disagreeableness, this closet may be made to answer its purpose. It is generally supplied with water by means of an ordinary tap, and where waste is feared, it may be prevented by the substitution of one of the simpler waste preventers in place of the tap which will limit the supply of water to a fixed quantity; or several closets may be cleansed at certain periods of the day by water turned on for the purpose independently of the users.

*As to Supply of Water to Water-Closets.*—Before dealing in detail with those appliances which regulate the supply of water to closets, it may be well to state that *in no case* can a direct supply from the general house cistern to the closet basin be recognised as right. Without dilating on the objections to the direct communication between a water-closet and the house cistern holding, as is generally the case, the water for cooking and drinking, it may be taken as a *sine quâ non* that all water closets should draw their supply from a cistern entirely disconnected from though probably fed by it.

In large houses where several closets exist one above the other it may not be advisable to have a separate cistern for each, though under any circumstances the quantity consumed should be regulated so as not to waste the supply. Where the quantity used is a measured quantity, it is generally limited to 2 gallons; but the great object to aim at is a perfect flushing of the basin which should be cleansed by the force rather than the quantity of water used. Under such circumstances one cistern reserved for the purpose may be all that is necessary, and the various modes of regulating the quantity drawn from it will be understood by the explanation given under the first and third class of waste preventers which follow.

Many are the supplemental appliances termed "Waste Preventers" and "Regulators" which have been designed to render water-closets more perfect in their use. Their purpose is to secure the flushing of the basin by the use of a certain and

sufficient quantity of water *and no more* each time the closet is used. In adopting any of these appliances care should be exercised that none but those constructed on sound principles are selected, otherwise their adoption is attended with annoyance.

The object to be gained is, as just stated, that the quantity shall be sufficient to completely wash and flush out the closet basin and traps without waste; and this will depend not upon the length of time the water is allowed to run, but upon the force and suddenness with which it is discharged. Waste preventers may be divided into three classes:—(1) Those that are fixed in a general cistern and which discharge a fixed quantity of water into each closet which such cistern is intended to serve. (2) Those which set free the contents of a small cistern, say two gallons, or of a compartment in a larger one holding a fixed quantity; and (3) those that effect the same purpose less directly, by means of a regulator placed under the seat of the closet, allowing only a fixed quantity to pass through it. All these contrivances when used for valve closets should have a means of ecuring the trapping of the basin by admitting sufficient water for that purpose after the valve has resumed its closed position.

*Waste preventing Valves fixed in Cisterns.*—In certain circumstances, as previously pointed out, it may be deemed advisable to adopt this form of waste prevention. It should, however, be borne in mind that, though this arrangement is a great improvement on the old valve arrangements of byegone days, inasmuch as it *does* prevent waste, it is still subject to the drawback of being placed in an inaccessible position.

Valves are always liable to derangement, and they therefore

FIG. 31.

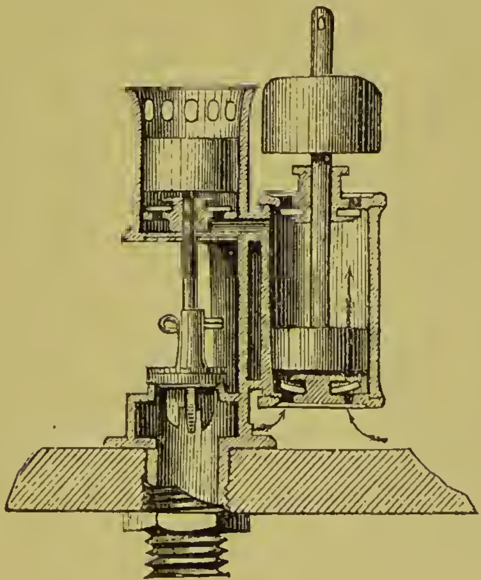
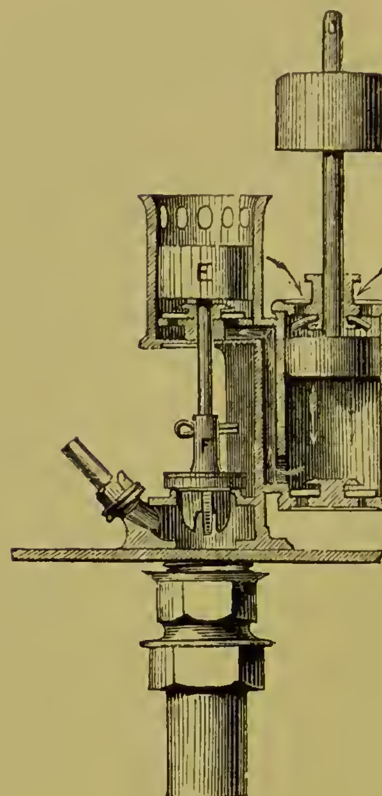


FIG. 32.



should never be put in places where it is not easy to get at them to rectify anything that may have got out of order.

Where waste preventers are placed in cisterns the "sure water waste preventer" of Messrs. Wallace and Connell (*see* Figs. 31 and 32) appears useful. This secures to the closet a certain quantity of water each time the handle is pulled up, and a second quantity to trap the closet contrivance after the handle is put down. Fig. 31 shows the contrivance when the closet handle is at rest; Fig. 32 shows it when raised. When the closet handle is raised the lateral cylinder of the valve is also raised, and the water above it is drawn in and forced up to the main cylinder in the direction of the arrows shown on Fig. 32. This water, entering the main cylinder suddenly, raises the piston E and the outlet valve to the closet (F). The piston E fits loosely, and is so weighted that while it will rise with the sudden rushing of the water up to it, it will afterwards gradually sink and force the water out past its circumference, and with its fall it will close the inlet valve to the closet. The time taken for the descent of the piston E will determine the quantity of water which can pass each time the closet handle is raised. When the closet handle is released the piston in the lateral cylinder will fall, and the water under it will be forcibly and suddenly pressed into the main cylinder, again raising

the piston E, and the valve F, and thus the outlet to the closet is opened a second time, the piston afterwards slowly descending as before, and this second discharge forms the trapping supply of the closet. This contrivance has therefore two distinct actions each time the closet is used—the first flushes the closet and the second gives the trapping water to the pan, and, however long the handle may be held up, this latter water is reserved until it is released. The holes at the top of the main cylinder limit the use of the piston by allowing of the escape of any excess of water forced under it.

The same object is secured by the "waste not" cistern valve of Messrs. Tylor (*see* Figs. 33 and 34).

FIG. 33.

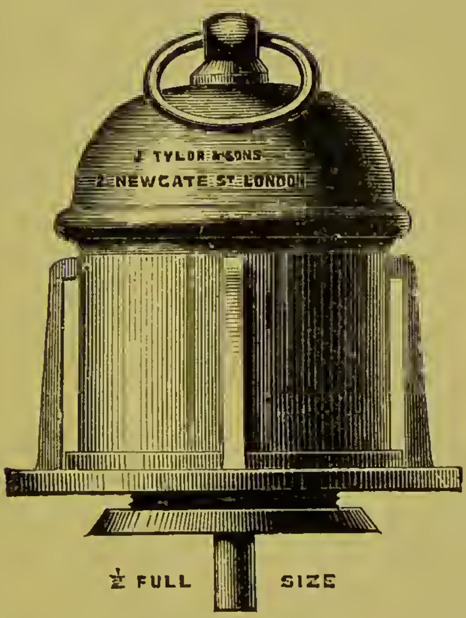
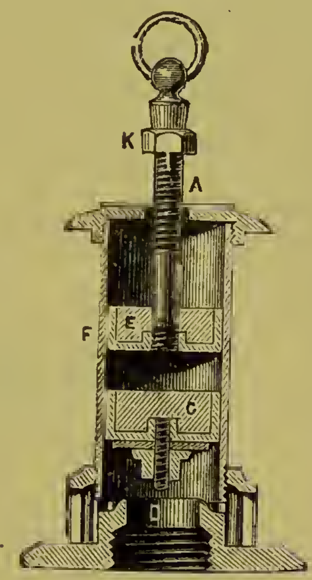



FIG. 34.




This valve, like the previous one, automatically closes after allowing the intended quantity of water to pass, or any less quantity in whatever position the closet handle which opens it may be left, thus preventing the running of an excessive quantity down the closet.

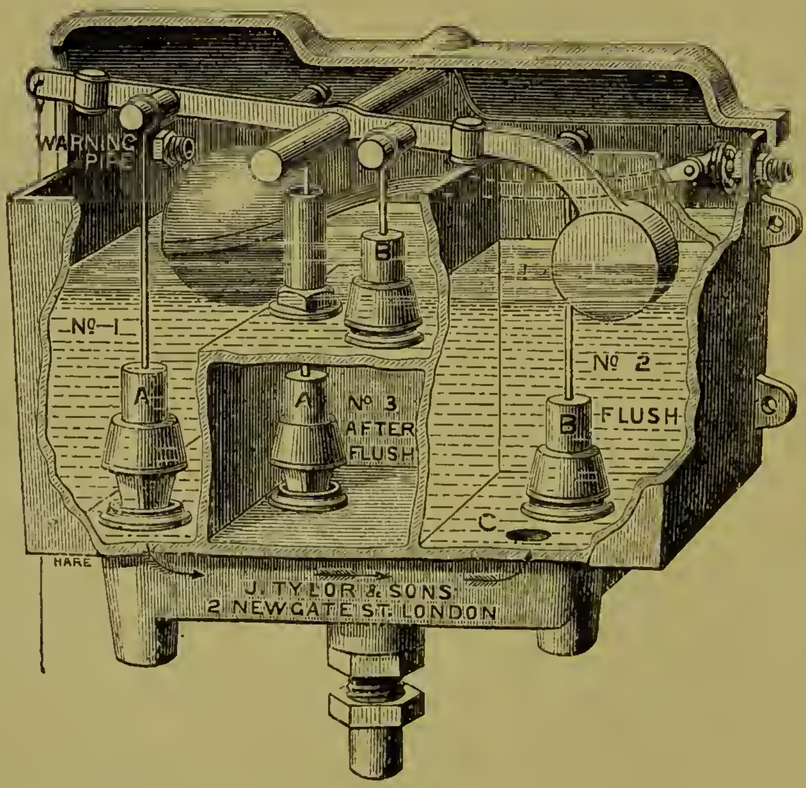
The piston regulating valve C (*see* Fig. 34), is fitted with a washer valve, and moves loosely up and down in a fixed cylinder F. E is an adjustable socket or piston. When the ball lever of the closet apparatus, which is attached to the spindle A, is pulled up it raises the adjustable socket or piston E, which takes up with it the piston regulating valve C, and opens the passage for the water through the valve. When the spindle A is dropped the piston E descends immediately and with it the valve C on to the

seating D, and the passage of water is closed. When the ball lever attached to spindle A is held or propped up the valve C descends gradually on to the seating D, and closes of itself with the stream, allowing only the intended quantity of water to pass. The quantity may be regulated according to wish by screwing down the nut K.

*Separate Waste-Preventing Cisterns fixed in each Water-Closet.*— This method appears after everything has been taken into consideration to be most efficacious in accomplishing the object aimed at. Care must be taken in fixing them that they should be placed in an accessible position at a height of at least 4 feet as directly over the closet as possible, so as to secure a direct and thorough flush, and the size of the delivery pipe should be at least 2 inches. It is a great advantage to be able to put into motion a second flush should the first fail to cleanse the basin. When acting in connection with a valve closet the wire should work inside a tube, while an ordinary pendant chain will be sufficient for use with a valveless closet. First among this class should be noticed the "after-flush waste-preventing closet cistern" of Messrs. Tylor, of Newgate Street, though its price would naturally deter many from using it.

Fig. 35 shows this invention at rest.

FIG. 35.



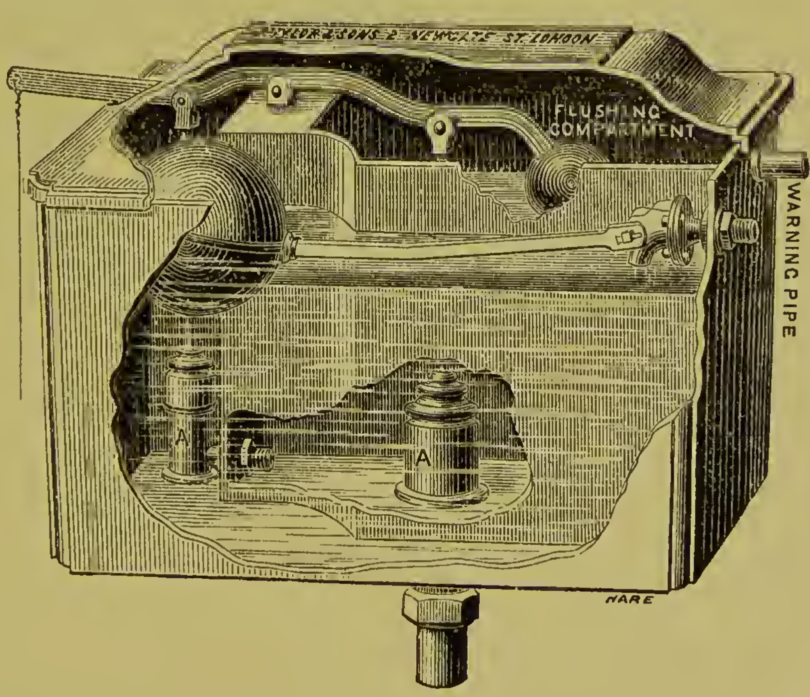

This apparatus consists of a cast-iron cistern about 20 inches

long, 11 inches wide, and 10 inches deep, having three compartments. In these compartments there are two pairs of valves AA and BB. When AA are open BB are shut, and *vice versâ.*

In Fig. 35 the valves AA are open and BB are shut. Directly the closet handle has been released after the closet has been used the water will have passed through the ball valve into compartment No. 1, and thence into compartment No. 2, through the aperture C by the passage shown by the direction of the arrows, filling both compartments, the after-flush compartment No. 3 remaining empty. When the handle of the closet has pulled down the lever and opened the valves BB, the water rushes out of compartment No. 2 and flushes the closet, and at the same time No. 3 "after-flush" compartment is filled from No. 1. When the handle of the closet is let down, the lever of the cistern falls with it, and the valves AA are again opened, and the water from the "after-flush" compartment No. 3 is discharged into the closet basin which it seals; the water from No. 1 running into No. 2 as already described. By this arrangement the trapping of the closet pan is secured as the water intended for that purpose is not discharged until the valve of the closet pan has been closed.

Fig. 36 shows Tylor's double valve waste-preventing closet cistern, which is somewhat less intricate aud costly than the previous example.

FIG. 36.

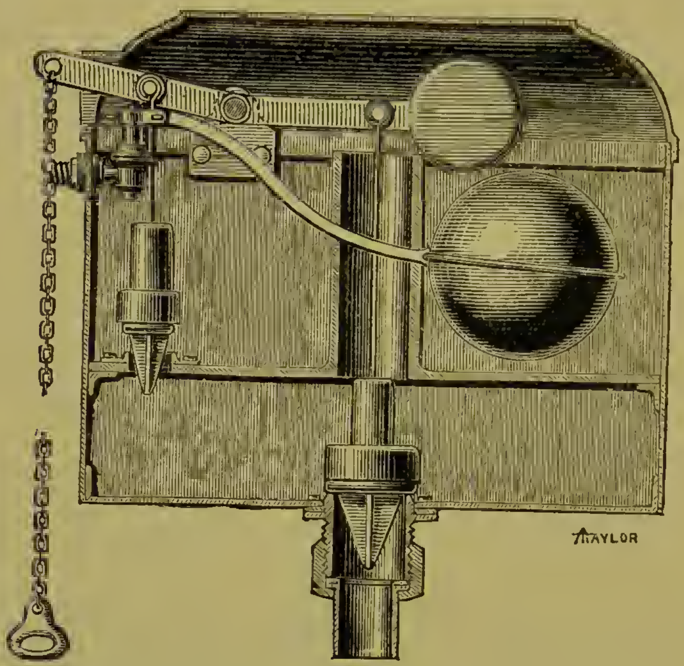



It is divided into two compartments, and is on the double-valve

principle. The two valves AA cannot be open at the same time, so that it is impossible to run a continual stream. It will discharge two gallons of water, or any part of it (but no more), at each flush, and has a small trapping compartment provided for the after-flush of the pan.

Fig. 37 represents another "improved double chambered water-waste preventer cistern" of Messrs. Stone and Co., which has been devised to answer the same purpose as the two preceding illustrations.

FIG. 37.



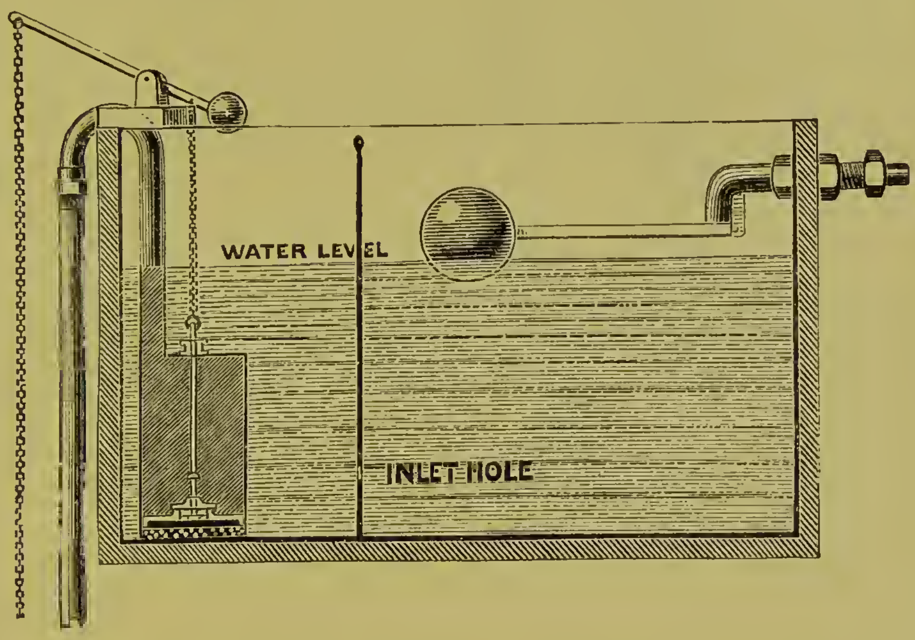

In this cistern also there are two chambers—an upper and a lower one. The upper chamber is filled by means of a ball valve and emptied through a discharge valve into the lower chamber which is constructed to hold two gallons. In the lower chamber there is also a discharge valve, and the apparatus is so arranged that the valve leading into the lower chamber, and that leading out of it, cannot be open at the same time. Thus, when the closet handle is pulled the top valve is closed and the bottom one opened.

It will have been noticed that in all the preceding illustrations of waste preventing cisterns there has been an absence of any mechanical action by which the cistern or that portion of it containing the required flush is emptied of its measured contents *with certainty*, no matter with what force or for what length of time the cistern is acted upon. This is doubtless a great desideratum, though it has its drawbacks, inasmuch as in some wash-out closets the fixed quantity fails on all occasions to clear the

basin, in which case a second and sometimes a third flush of the same quantity is a matter of necessity, although if the first flush had been continued for a time when put into action, a great saving would have been effected.

To effect the discharge of a fixed quantity and no more, the invention of Messrs. Braithwaite, of Leeds (*see* Fig. 38), has much to recommend it. In this instance a syphon is made the discharging medium, which does away with any possibility of the leakage and derangement, so often consequent on the adoption of valves.

FIG. 38.

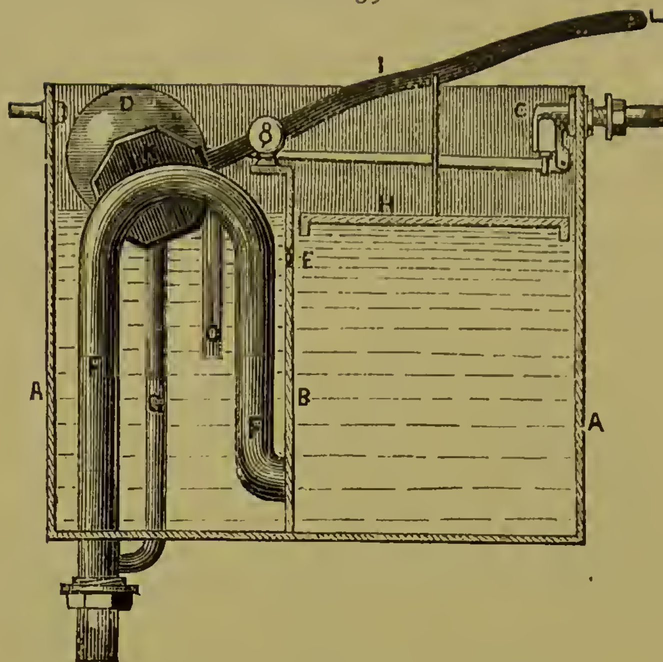



In the above drawing the syphon is, as may be seen, fixed in a cistern divided into two compartments, but connected by a small hole in the partition; one compartment being for the ball tap to work in, and the other to regulate the supply. The service pipe to the closet is brought into the first compartment in the manner shown, and in the other is a cylinder in which works a piston that being raised forces the water into the syphon pipe and over its crown. The syphon is thus set in motion, when a loose plate in he bottom of the cylinder rises and allows the water to flow.

The double-syphon water-waste preventer by E. Emanuel, of Marylebone Lane, London, is another good example of a waste preventer of this sort.

An after-flush is provided by the use of a second syphon, much smaller than the first, which renders the invention especially deserving of notice. Fig. 39 shows this water-waste preventer, which is thus described by its inventor.

FIG. 39.






"A is a cistern divided into two compartments by a partition B. Water is supplied from a water supply pipe to the right hand compartment through a ball cock C, the ball, or float, D, of which is in the left hand compartment. In the partition B, is an opening E, and when the right hand compartment is filled with water up to this opening, water flows through it into the left hand compartment, and fills that also until by the rising of the float D, the supply valve C is closed. F is a syphon pipe, the shorter limb of which opens into the right hand compartment of the cistern, and the longer limb of which is carried down to the closet pan or basin. G is syphon pipe of smaller diameter; its shorter limb opens into the left hand compartment of the cistern, and its longer limb is led into the longer limb of the syphon F. H is a plate or float fitting loosely to the sides of the right hand compartment. It is attached to one arm of a lever I, and is held up by a weight K fixed to the other arm of the lever. A wire is attached to the lever at L, and when the wire is pulled downwards, by the action of the closet handle in the ordinary manner, the plate or float H is forced downwards. Water is thus forced into the larger syphon, and this syphon becomes charged and at once empties the right hand compartment into the closet basin, the smaller syphon also becomes charged, and when the right hand compartment has been emptied, continues to deliver a small stream of water into the syphon F, until the water level in the left hand compartment gets below the end of the shorter limb of the smaller syphon. As the water level in the left hand compartment descends, the valve C opens and again fills the

cistern, the right hand compartment being the first to fill as explained."

Messrs. Brazier, of the Blackfriars Road, and Mr. Purnell, of Westminster, have both invented syphon waste preventers, but the experience gained of these contrivances does not enable us to say more than that they each possess some of the elements of success. In both examples, as in the case of Braithwaite's and Emanuel's, directly the syphon is brought into action, the water should be delivered and should continue to discharge with nearly equal force from the beginning to the end when a dribble at the last should be impossible. It should not matter whether the handle is let go directly or held for a time, the required quantity of water should be discharged in either case and no more. Thus while waste is prevented an effectual flush to the closet is ensured, which, as one inventor points out, is a great advantage when the carelessness of servants is considered, who very often, after emptying their slops down the closet, just give the handle a slight pull and leave it.

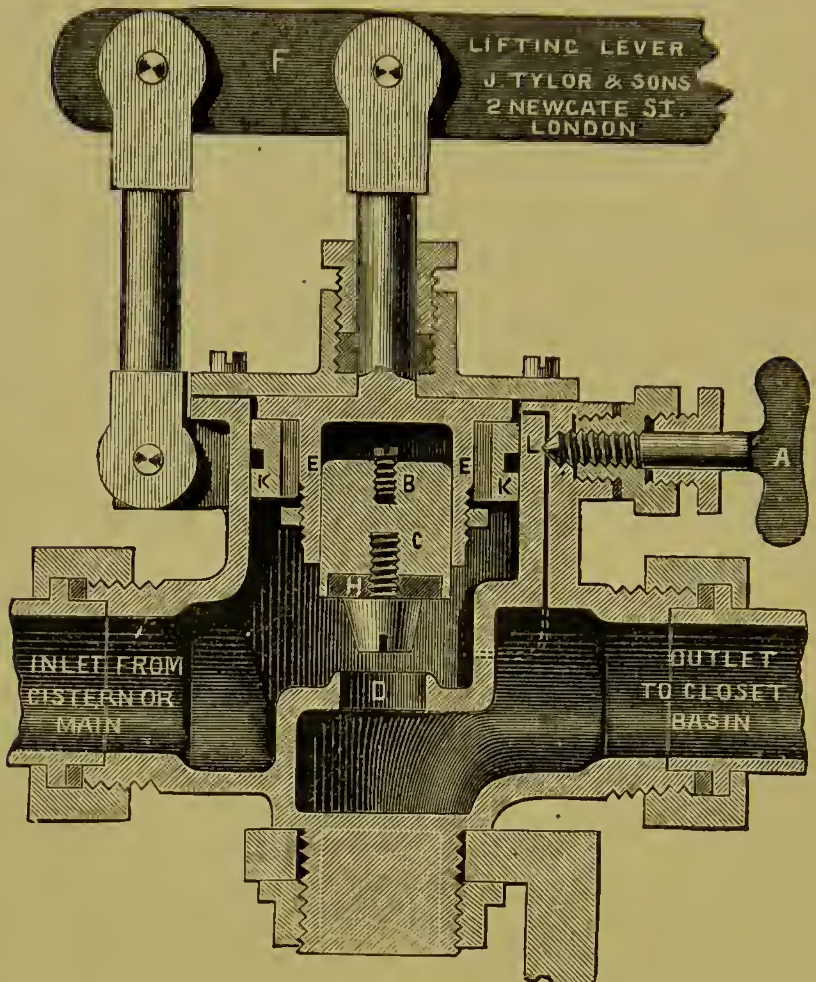
*Waste Preventers and Regulators fixed under the Seats of Closets.*—Although many authorities on the subject consider that waste of water is better prevented by the use of cisterns placed above the seat of the closet, and which discharge a fixed quantity each time they are acted upon, there are others who prefer those placed *under* the closet seat.

They possess the following advantages:—(1) They naturally occupy less room in the closet itself; (2) Any number of closets can be supplied by one service pipe from the cistern above; (3) There is no interval between the raising of the handle and the inrush of water into the basin.

The disadvantages are—(1) Less force is obtained in flushing out the basin, which should be a primary object; (2) The arrangement is not mechanically so durable; and (3) There is not generally that thorough disconnection from the general water supply which should always be aimed at.

Under this heading Fig. 40 represents on a large scale Messrs. Tylor's "waste preventer," which may be safely and advantageously used where the supply of water is obtained from a cistern serving more than one closet, or where the supply cistern being placed over the closet, the outflow from it is not limited to a fixed quantity. Here C is a plunger fitted with a washer valve H at the bottom, and moving up and down in a metal or elastic socket EE, which forms a carrier, and which is fixed to the spindle connected with the lifting lever F. This valve is made, when preferred, with a flat elastic washer or diaphragm (instead of EE). KK is a ring valve for the purpose of controlling the descent of the metal or elastic socket EE. L is a passage way by which the water flows from under to above the ring valve KK,

FIG. 40.

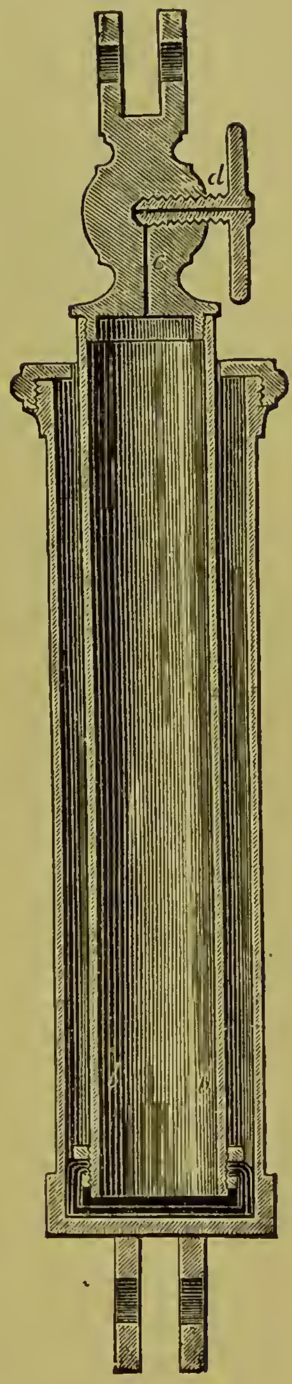



and is partially opened or shut by turning the tap A. When the handle of the closet is pulled up, the lever F raises the metal or elastic socket EE which lifts by suction the ring valve KK, and the plunger C, and thus opens the passage for water through the valve. When the handle is dropped the lever F commences to fall, the speed of its descent being regulated by the quantity of water which is allowed to pass through the passage way L. If the closet lever F is held up, the metal or elastic socket EE and ring valve KK will be kept up too, but the plunger C will be taken down on to its seat D, partly by its gravity, but principally by the pressure of the water. The adhesion or attraction should cease, and the plunger C begins to fall, when the pressure is made equal inside and outside the socket.

The patent regulator of Underhay, referred to in connection with the water-closet, Fig. 23, is shown upon an enlarged scale by Fig. 41.

The object of this invention, which cannot be termed a waste preventer, is to allow the passage of a certain quantity of water through the pan of the closet each time the handle is raised, even if it be dropped again instantaneously. For this purpose a vessel, by preference a cylindrical vessel, is adopted, which is closed at the bottom, and provided with an air inlet near the top. Within this is a second cylinder which is open at the top to a small extent only, but entirely open at the bottom. The inner vessel is of such dimensions as will allow of its working up and down readily within the outer one. Around and near the lower part of the inner vessel is a cup of leather or other suitable flexible material, the lower edge of which descends into some lubricating fluid at the bottom of the outer vessel each time the inner vessel is caused to descend. By this means the interior of the outer vessel is lubricated each time the inner vessel is raised. At the upper end of the inner vessel an air cock C with regulating screw D is provided, the latter being adjusted according to the time which it may be desired the inner vessel should take in descending. The outer vessel is fixed in any convenient position, and the inner vessel is connected with the closet handle. When the latter is raised the inner vesssel above mentioned is also raised, which can readily be done by reason of the cupped leather giving way, and acting as a valve. A certain quantity of air will be admitted by this process to the bottom of the inner cylinder. When the closet handle is left to fall back, the pressure of the air will keep the outer edge of the leather against the interior surface of the outer vessel, and the inner cylinder will only descend as the air escapes by the air valve mentioned. In this way the lever of the closet is kept open for the discharge of water until the inner cylinder has descended to the bottom. This occurs each time the closet handle is raised.

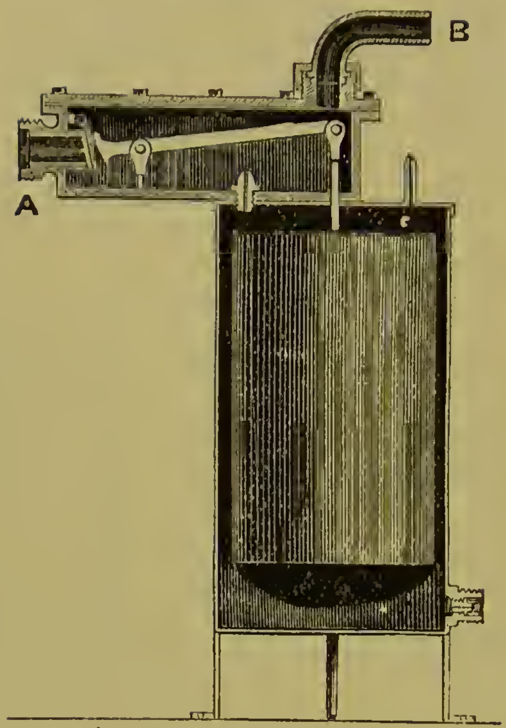
FIG. 41.




Underhay's "waste preventer" is shown by Fig. 42.

This instrument is in principle somewhat similar to the "regulator." Like that contrivance it consists of one cylinder within

FIG. 42.

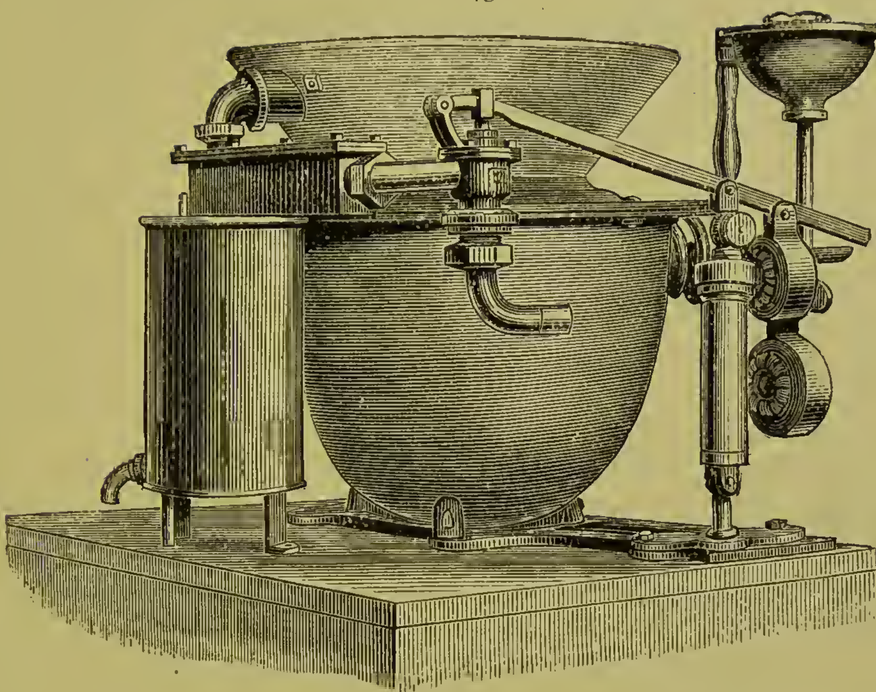



another, and as the water runs from the cistern or supply pipe to the pan of the closet (from A to B) a certain regulated proportion escapes through the small aperture shown on the figure into the space between the outer and inner cylinders. Within a determined period this influx of water floats, and gradually raises the inner cylinder, which, being connected with a lever for the purpose, closes a valve in the water supply pipe A, and prevents the entry of any further water until the preventer has had time to empty itself of its contents by the small outlet at the bottom. By the combined use of these two last appliances it will be found (1) that the closet handle cannot replace itself and close the supply valve until the pan has been well flushed; and (2) that no more than a certain quantity of water can be used at one time.

Fig. 43 shows the relative positions of both the "regulator" and "waste preventer" with reference to the closet.

*Trapping Box for securing an after-flush when not fitted to Water Waste-Preventing Cisterns,*—Although the adoption of water-waste preventing apparatus of some description or another, containing and delivering a restricted quantity of water, is now almost universal, still, as has been shown in the preceding paragraphs, a means for securing a certain after-flush is not always provided. This after-flush should invariably be insisted on where valve closets are used; and no waste preventer of the 1st or 2nd class should be fitted to a closet without this additional flushing chamber, for when it is absent, and

FIG. 43.

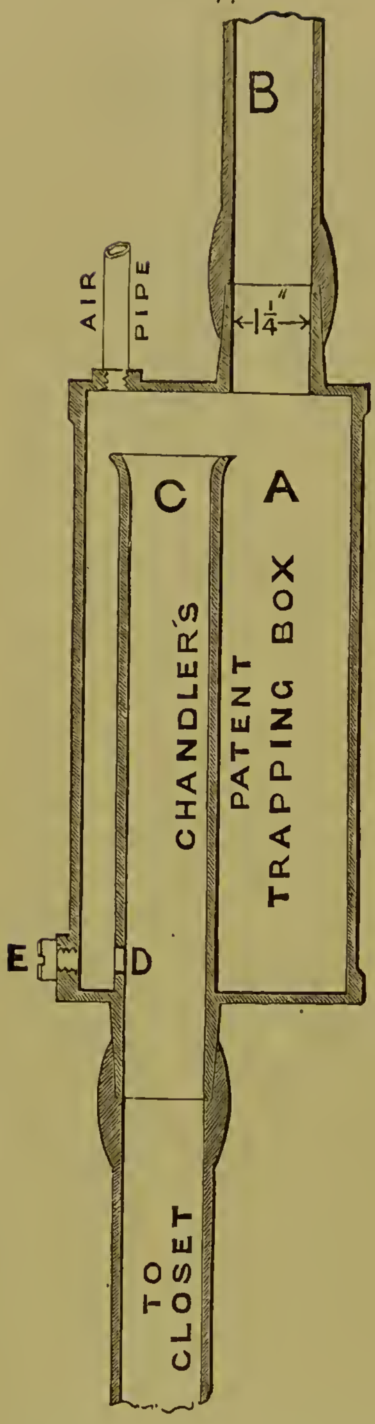


the closet is not in constant use, the valve trap will become unsealed, and the extra safety obtained by double trapping will be done away with. Messrs. Chandler, of Mile End Road, have invented and patented a trapping box which may be connected with the down pipe anywhere between the water cistern and the basin of the closet (*see* Fig. 44). In this invention the contents of the trapping box A, which must necessarily be filled with water from the cistern above, each time the closet handle is raised, is made to discharge itself through the small aperture D into the pan of the closet after the first flush has been delivered. By withdrawing the screw E, a ready means of cleaning the aperture D is obtained, should it be blocked up at any time. The invention seems very simple, and cannot get out of order.

XLII.—EARTH CLOSETS.—As previously stated, the solid portions of the sewage of all well-ordered dwellings, especially the excrementitious contents of outside closets, require only careful collection and frequent periodical removal to render them free from nuisance.

With the condemnation of leaky and overflowing cesspits, dry closets for the disposal of excretal refuse in rural districts are daily coming more and more into use in the place of common privies; while in the northern manufacturing towns, where "middens"—which have been declared to be "the standard of all that is utterly wrong"—are the common receptacles of the excreta of their inhabitants, great efforts are being made to

FIG. 44.




introduce in their place movable pails or boxes with disinfectants or absorbent linings.

Many excellent forms of closet are now before the public, foremost amongst which stands that of the originator of the dry system, the Rev. Mr. Moule, whose invention, having been patented, has passed into the hands of a company by whose instrumentality it is finding its way into general use. Dry closets are particularly suitable for the poorer dwellings of country towns, villages and hamlets, where water is scarce and where water-closets would therefore be out of place. But there is no disguising the fact that the best dry closet is invariably associated with a vapid smell which becomes extremely objectionable when the closet is not kept properly cleansed. This condition is greatly due to the difficulty which is found in absorbing and deodorising the whole of the urine by any of the materials used for the purpose.

To overcome this drawback Mr. Gibson, of Clapham, has invented a closet intended to separate the urine from the solid portions of the excreta, and allow the former to pass away by a distinct channel. Fig. 45 shows this closet and explains the arrangement.

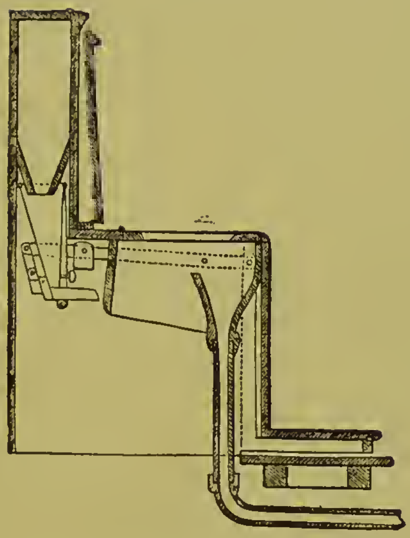
The dry material may be either earth, ashes, or charcoal.

The patent closet of Dr. Bond, of Gloucester, is also designed for the separation of the urine from the fæces. The dry material (ashes or earth) is distributed over the fæcal matter by the shutting of the lid of the closet.

Fig. 46 shows another kind of dry closet made by Messrs. King, of Moscow Terrace, Victoria Park, in which the dry material is distributed on the contents of the pail by the action of the lid, as in the case of Dr. Bond's closet.

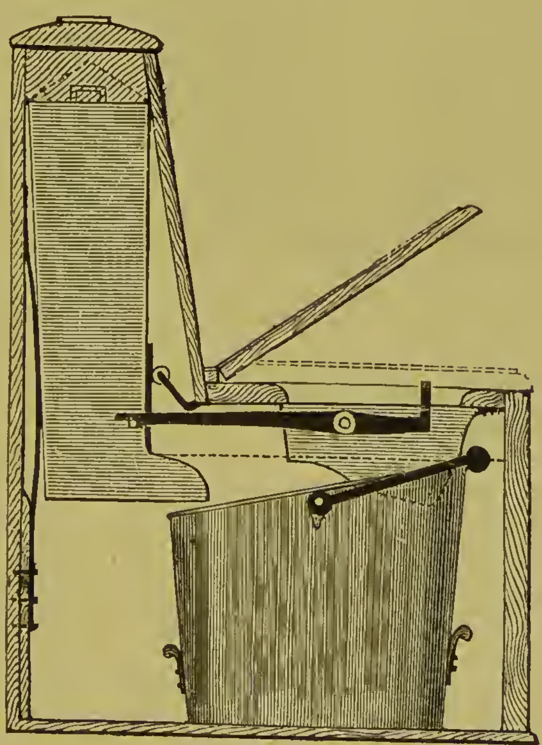
The action of a closet-lid as a means of spreading ashes or dry earth upon excretal matter deposited under the seat commends

FIG. 45.



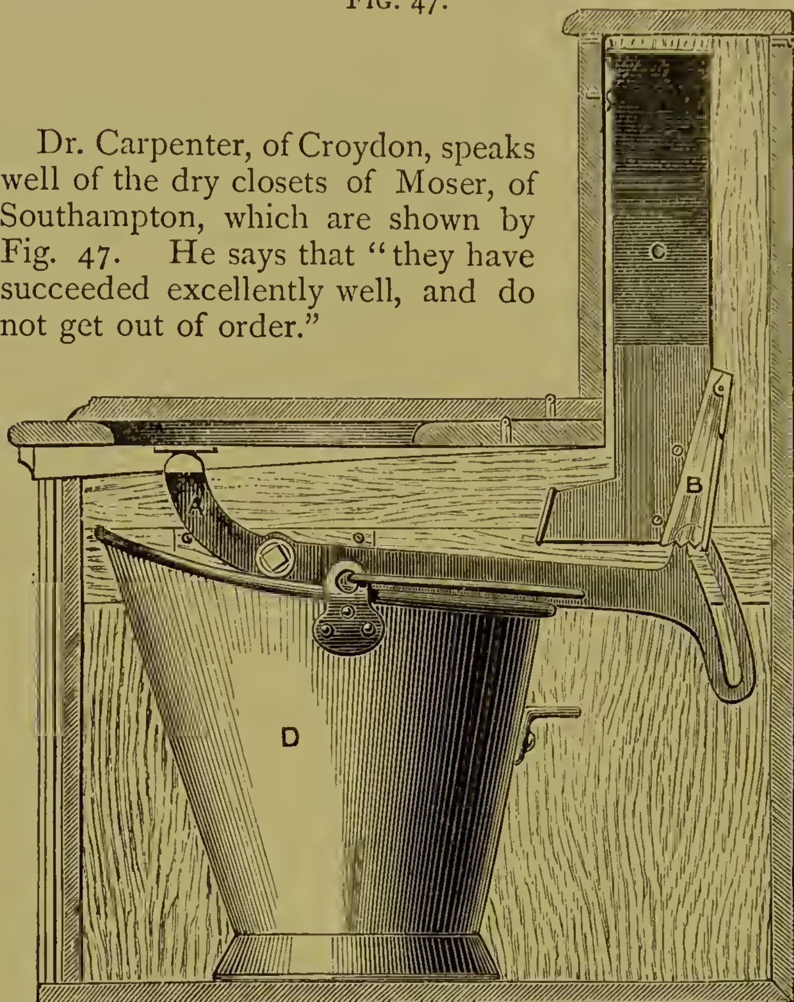
itself to a mechanic, because the lid is easily capable of being connected with a rod running under the floor of the closet which could be made to throw out a bolt and so fasten the door of the closet when the lid is lifted up. By the same connection the closing of the lid may be made to withdraw the bolt and so allow

FIG. 46.



the door to be opened without which the person who has used the closet could not leave it. Thus the covering of the excretal matter with the dry material will be ensured, in spite of the carelessness which so often prevails.

FIG. 47.




Dr. Carpenter, of Croydon, speaks well of the dry closets of Moser, of Southampton, which are shown by Fig. 47. He says that "they have succeeded excellently well, and do not get out of order."

The closet is made to act by means of a spring seat, which, when used, moves the lever A, which acts on the bellows B, and throws a quantity of the dry material (ashes, &c., mixed with sawdust, charcoal, spent dye woods, or dry earthy material contained in box C) over the contents of the pail D.

It is not, however, because the compound of dry earth and organic matter obtained by the use of these closets is commercially valuable that the dry system is gaining ground, for Dr. Gilbert, in the trials made on behalf of the Sewage Committee of the British Association, found that when ordinary field soil was used as the dry material the increase in the percentage of nitrogen was only ·015 each time the soil was used, and that even after being used twice, it was not richer than good garden mould.

The advance of the dry system into public favour is therefore

on the whole due rather to the difficulty of providing water than to the value of the product, for though the erection of an earth closet is less costly than a water-clǒset, and it is neither injured by frost nor by improper substances being thrown down it, a well-arranged water closet with plenty of water at command is always preferable to any earth closet that could be devised, so far as cleanliness and order are concerned.

It is when circumstances prevent the supply of the requisite quantity of water that earth closets have the advantage.

It should be added that though the intending purchaser cannot do wrong by adopting Mr. Moule's invention there have been slight improvements resulting from subsequent investigation, and that the foregoing illustrations are intended to show to those interested in the subject that by enquiring into the matter themselves they will probably be able to obtain what will most likely be suitable to their individual purpose.

XLIII.—Sink Traps.—In order to prevent sewer gas passing into the dwelling by the discharge pipes of sinks, it is necessary, even after the adoption of such outside traps and disconnecting arrangements as were described in the last chapter, to have these pipes trapped immediately below the sink, for unless such precaution is taken effluvium will be drawn in through them from the external trap by the greater warmth of the inside air, while the organic matter which must hang to the inner sides of the pipes may of itself become a nuisance as it putrifies. The simplest traps are best for the object in view, and the more securely they are fixed in their places, so that they cannot be easily put out of order or removed by servants or children, the more likely they are to answer their purpose satisfactorily. This precaution is especially necessary in the case of upstair sinks, which are too often connected with the soil pipe of the water-closet.

Figs. 48 and 49 represent the very useful sink trap of Messrs Tye and Andrews, of Brixton Road.

As will be observed, at the bend of the syphon, screws or small

Fig. 48.

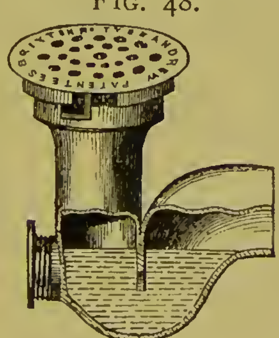
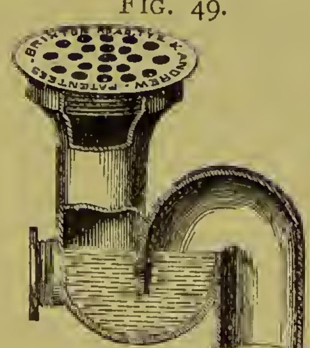


Fig. 49.



caps are provided for examination, and for the removal of any stoppage that may occur in them.

Messrs. Dent and Hellyer, of Newcastle Street, Strand, and Messrs. Sutcliffe, of Halifax, manufacture some excellent sink-traps which are very similar to the preceding illustration, and equally effective.

Figs. 50 and 51 show the "registered waste pipe and grating" of Messrs. Adams and Son, Haymarket, London.

Fig. 50.

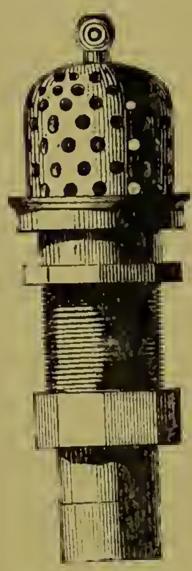


Fig. 51.

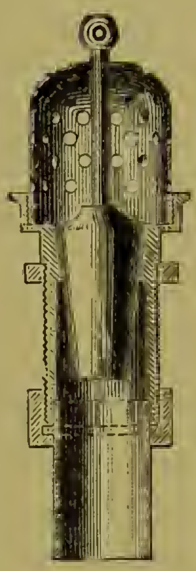
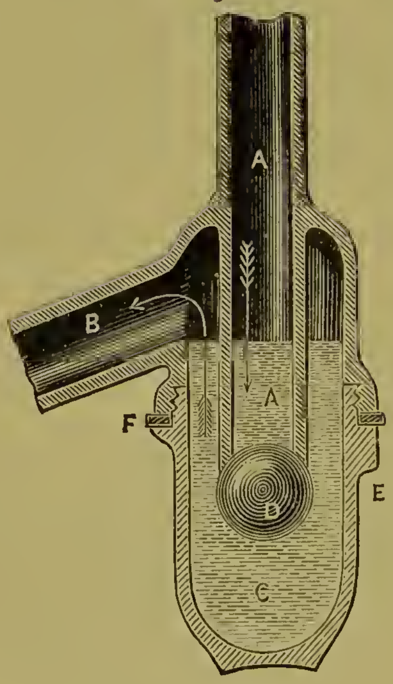


Fig. 52.




In this example the air-tight plug fitting into the down pipe, and forming the required disconnection, has to be raised to allow the liquid to escape, and this trouble may be considered a drawback.

Fig. 52 shows the Bower trap, which is also another means for the prevention of the rising of sewer gas into the dwelling. In this figure, as will be readily seen, A is the down pipe from the sink, B the outlet pipe to the sewer, C the cupshaped chamber removable for cleansing purposes with a floating valve or ball D in it, which automatically constitutes the trap. The makers state that it will resist the greatest pressure from without, which is a great advantage over other traps, if the ball obtains its seat perfectly.

As may be judged by looking at the

drawing, any upward pressure of air or water against the trap is well resisted, and the constant depth of water always in the trap renders unsyphonage almost impossible. Glass cups or chambers to hold the ball are provided to these traps which prove very useful for inspection. Jennings, of Lambeth, likewise has invented a trap very similar in construction to the Bower trap.

These three sorts of traps and other traps constructed on the same principles have superseded the old "bell trap" and the "antil trap," which have been frequently found incapable of preventing the escape of effluvia, and are therefore generally rejected for house use. In places, nevertheless, where these traps have been well fixed, and there is a discharge of water only, and that discharge is constant, or of sufficient frequency to keep the trapping charged, they answer their purpose well.

XLIV.—Grease Traps.—In cases where it is impossible to discharge the refuse of the kitchen or scullery sink directly over the grating of an outside flushing trap — and this is frequently the case in town houses—it is possible to minimize the evil consequent on the collection of grease by the adoption of a trap designed specially to intercept it. A grease trap is generally placed beneath the scullery sink, so as to be out of the way. It is constructed either of iron or earthenware. In it the fat, which is generally in a semi-liquid state when turned down the scullery sink, is arrested and solidified, the liquid passing on into the main outfall sewer. The danger of the house sewer becoming choked up by an accumulation of fat is thus removed.

In cases where grease traps are necessary the simplest in con struction should be adopted and the greatest possible care exercised to ensure their being regularly cleaned out, for if they are not, the remedy becomes worse than the disease. It is for this reason that those erected above the floor level are to be preferred to those placed below, inasmuch as they are more likely to obtain attention. The cover should be made air tight, and so fixed as to prevent effluvium rising up into the scullery, and the trap itself should be ventilated, if possible, so that any confined gases may escape direct into the open air.

Fig. 53 shows the grease trap made by Messrs. Stidder, of Southwark.

It is constructed of iron and erected above the floor level. It has a door in the front cheek for the purpose of clearing out the trap, with a lip to empty the fat into a pail for removal.

The arrows sufficiently indicate the flow of the scullery water without any further description. The invention seems to fully answer the objects aimed at.

FIG. 53.

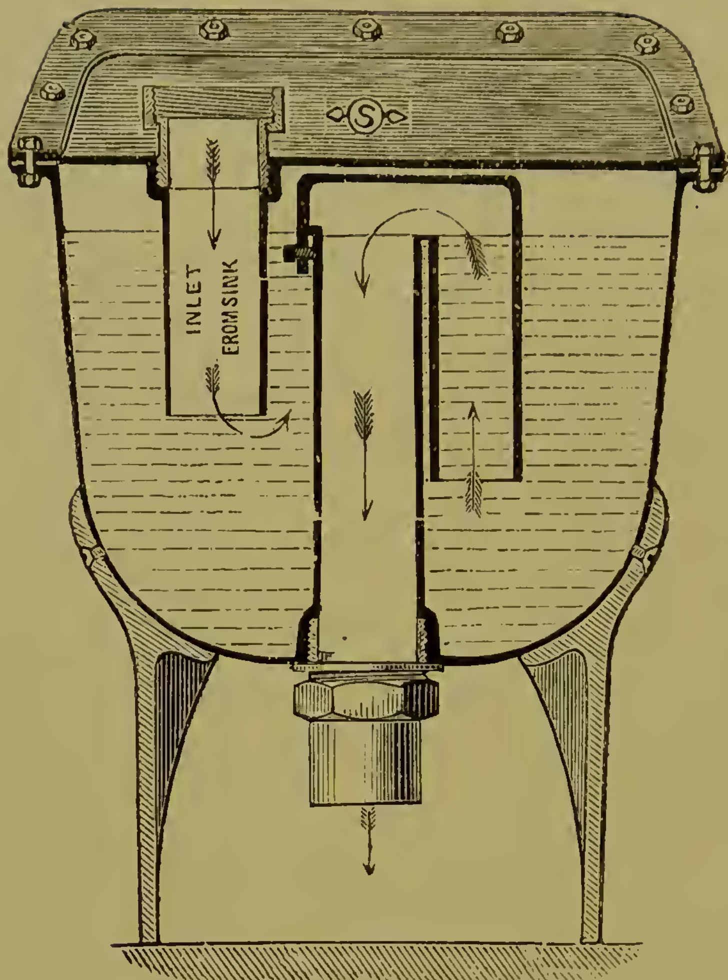
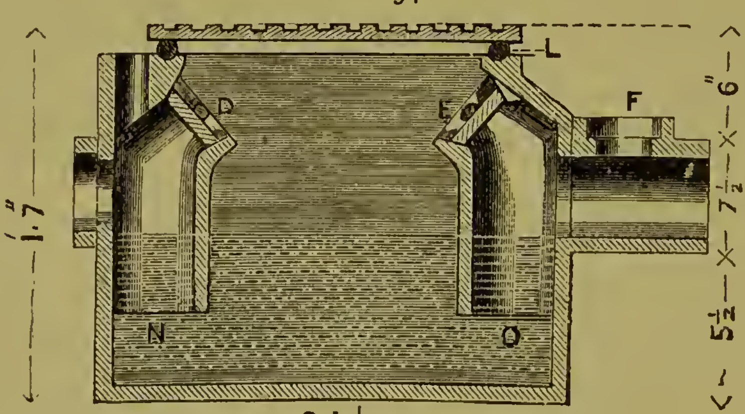





Fig. 54 shows an equally good invention in earthenware, of Mr. Hellyer, of Newcastle Street, Strand.

FIG. 54.



The water from the sink enters the trap by the pipe at N, and the outgoing pipe is shown at O, being in both cases a few inches below the standing water. Ample means is, as shown, given for cleaning out and removing the solid deposit in the trap, and a pipe for external ventilation is also provided.

XLV.—Housemaids' Closets and Sinks.—Next in importance to the water-closets in the upper floors of a dwelling the housemaid's closet deserves consideration as the sink it contains serves for the discharge of all upstairs slops. In large mansions or public institutions it is almost necessary that there should be one on every landing, while in smaller dwellings a single one for the entire house may suffice. By their adoption not only is much manual labour saved to servants, but the water-closet apparatus, which most frequently does duty as a sink in the absence of special arrangements, is protected from derangement.

Most of the housemaids' sinks that have been invented aim at the same object—the discharge of liquid refuse—though others combine with this object other and additional services.

In every case there should be a water supply at hand to flush the discharge pipes whenever necessary. It is a matter of considerable importance that they should be efficiently trapped, inasmuch as they are generally connected with the soil pipe of the water-closet from whence sewer air may rise. Housemaids' closets, too, should never be placed in conspicuous places, as they are generally subject to a disagreeable, though slight odour, which renders outside ventilation advisable and cleanliness indispensable.

Fig. 55.

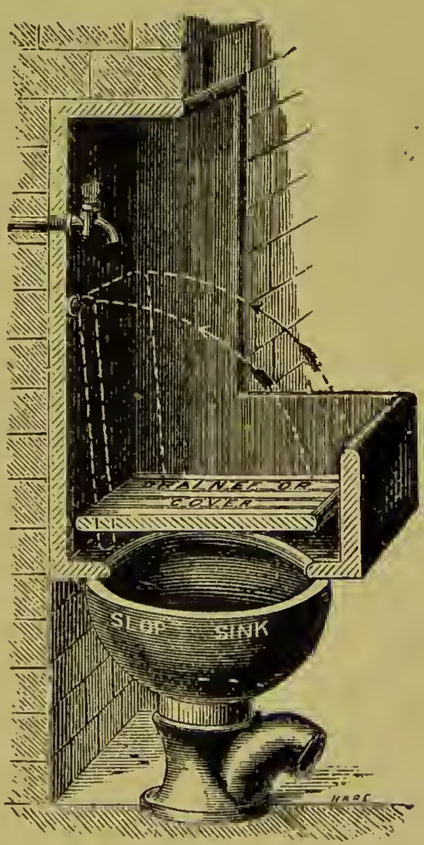
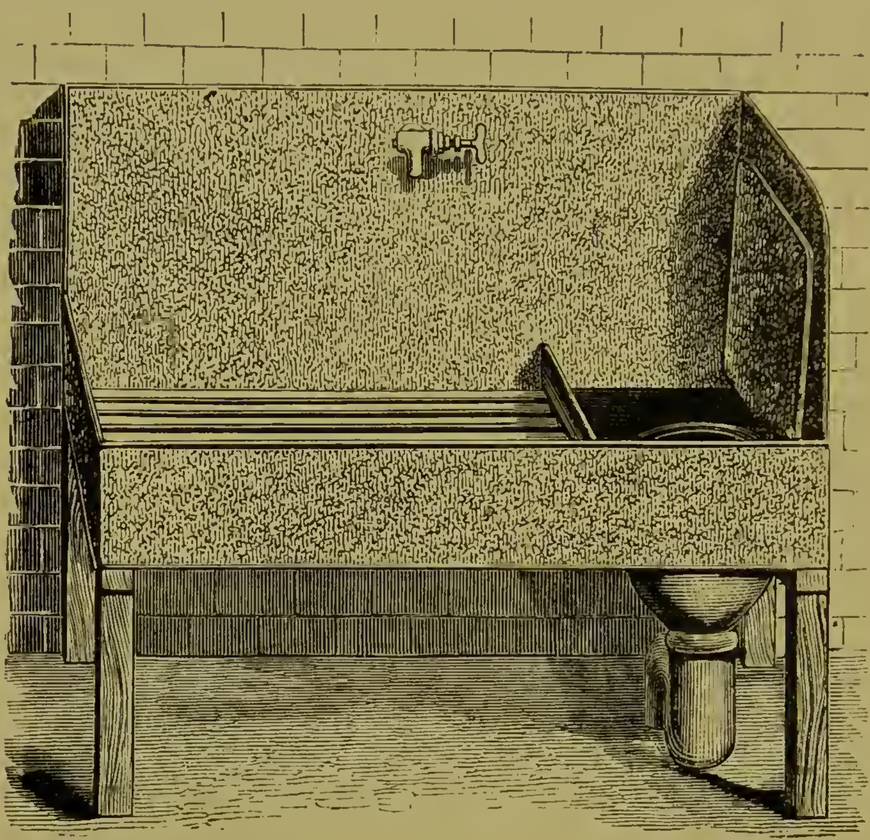



Fig. 55 shows Jennings' housemaid's sink adapted to the upper floors of mansions where it will be found extremely appropriate for the discharge of bath and slop waters removed from bedrooms. It is accessibly trapped above the floor line, and is provided, as may be noticed, with a movable slatted cover to keep back the larger materials which might otherwise choke the trap. It should be provided with a tap for the supply of water for chamber purposes and for flushing out the sink whenever necessary.

One of Doulton's housemaid's sinks, on a somewhat larger scale (being a wash-up and slop sink combined) is shown by Fig. 56.

FIG. 56.

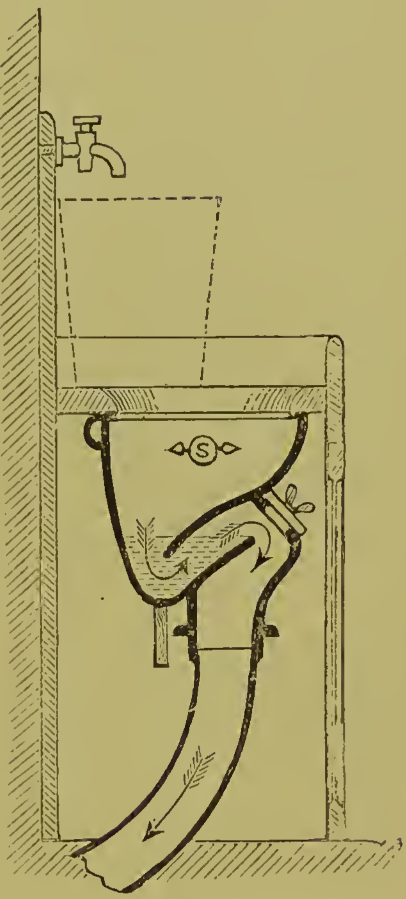


It is provided with an earthenware basin sufficiently capacious to receive the contents of pails or other utensils, and is trapped above the floor level. The sink, wherever practicable, should be fitted with both hot and cold water taps.

Fig. 57 shows a section of the Holborn slop sink made by Stidder and Co.

It is accessibly trapped, and being compact may be advantageously adapted to small dwellings where space is an object, though it must be acknowledged that its ventilation seems defective. This last remark, it should be added, appears, if one may judge from the illustrations given, to apply equally to all housemaids' sinks. It is therefore the greater reason why frequent flushing should be insisted on, and where the sinks are close to an external wall that ventilation of the pipe leading to the soil pipe should be added.

Fig. 57.



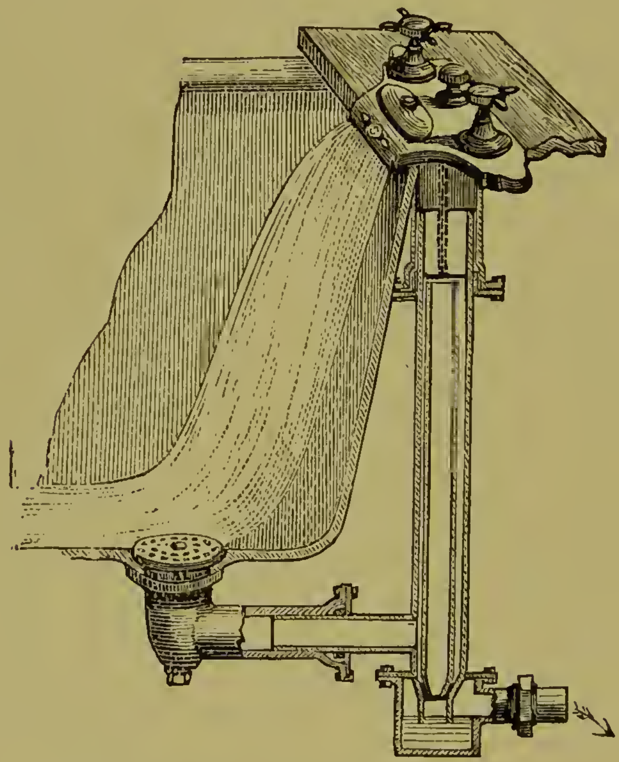
XLVI.—Bath Rooms and Bath Appliances.—It is now generally acknowledged that a dwelling cannot be considered complete without a bath-room, and that its adoption should not be limited to the superior mansions of the wealthy, but that all classes of our population should have it in their power to benefit by the comfort, cleanliness, and healthfulness afforded by both hot and cold baths. In large mansions and hotels there should be one or more bath-rooms on every bedroom floor, while in all averaged sized dwellings one placed in a central position will be found to be all that may be positively necessary to meet requirements. In country houses, where the lavatory is in frequent use, and it can be made to conform to a compound arrangement embracing, besides the ordinary accommodation of a lavatory, a bath, a water-closet (for occasional use), and a urinal, the ground floor will be its best position, in which case it should consist of two apartments, the lavatory forming an ante-room to the bath-room and water-closet. In small dwellings it is by no means necessary that the bath-room should be supplied with all such modern and luxurious improvements and the most simple and economical arrangements will suffice.

For mansions, hospitals, and other kindred institutions where the latest improvements are required, there are numerous sorts of baths before the public. Where baths are used in rapid and continued succession, earthenware and masonry will be found most applicable, for although such materials at first absorb a great quantity of heat, they afterwards retain it for a long time. For superior dwellings, copper baths should be used in preference to enamelled metal of any kind, for enamel after a time flies and breaks owing to the expansion and contraction of the metal it covers. This objection also applies to japanned zinc and iron, for in both cases the japan after a time wears off. In addition to these considerations, it may be said that copper baths after some years of use can always be made at a trifling cost as good as new, or if sold the metal will realize an eighth of its original cost. The most useful length of baths is five and a half feet at the top and

four and a half feet at the bottom, with a depth of two feet three inches. Where fixed on upper floors, they ought invariably to be provided with a lead safe.

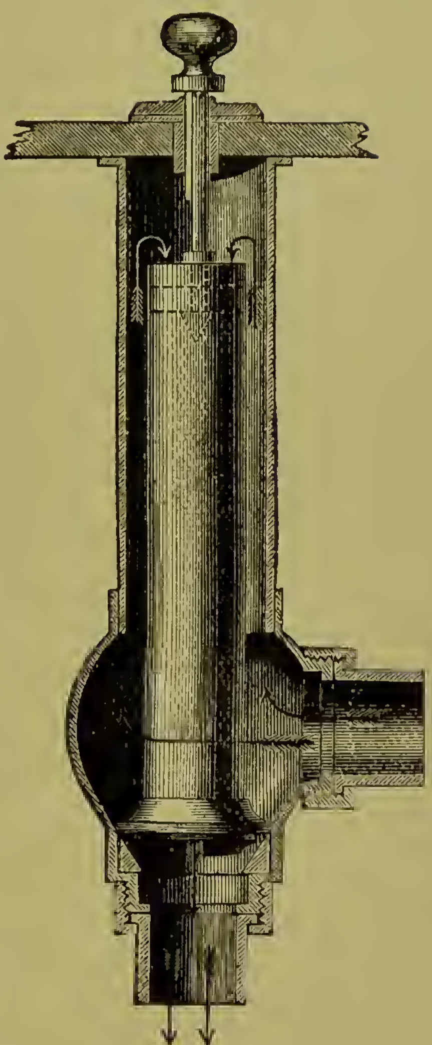
The hot and cold water inlets, instead of being at the bottom of the bath, as may be frequently seen, should be placed a little distance up it, or as is required by the water companies of the metropolis, above the overflow. This is done in order that the water, as it enters the bath, may be both seen and heard. The system, however, is open to objection, for when the supply from the boiler is very hot, the bath-room becomes speedily filled with steam. To obviate this, as pointed out by Mr. Hellyer, the inlets both hot and cold should be placed at a height of a few inches above the bottom, and the bath should be filled up to a few inches above the hot water inlet with cold water before the hot is admitted. Fig. 58 shows Messrs. Stidder's method of complying with the requirements of the metropolitan water companies.

FIG. 58.



In no case should the same opening act as inlet for supply as well as a waste, for when this is the case, not only must some of the soap-suds and other floating matter discharged on the last occasion of use return to the bath when the water is next admitted, but in cases of contagious personal ailments infection may be easily caused.

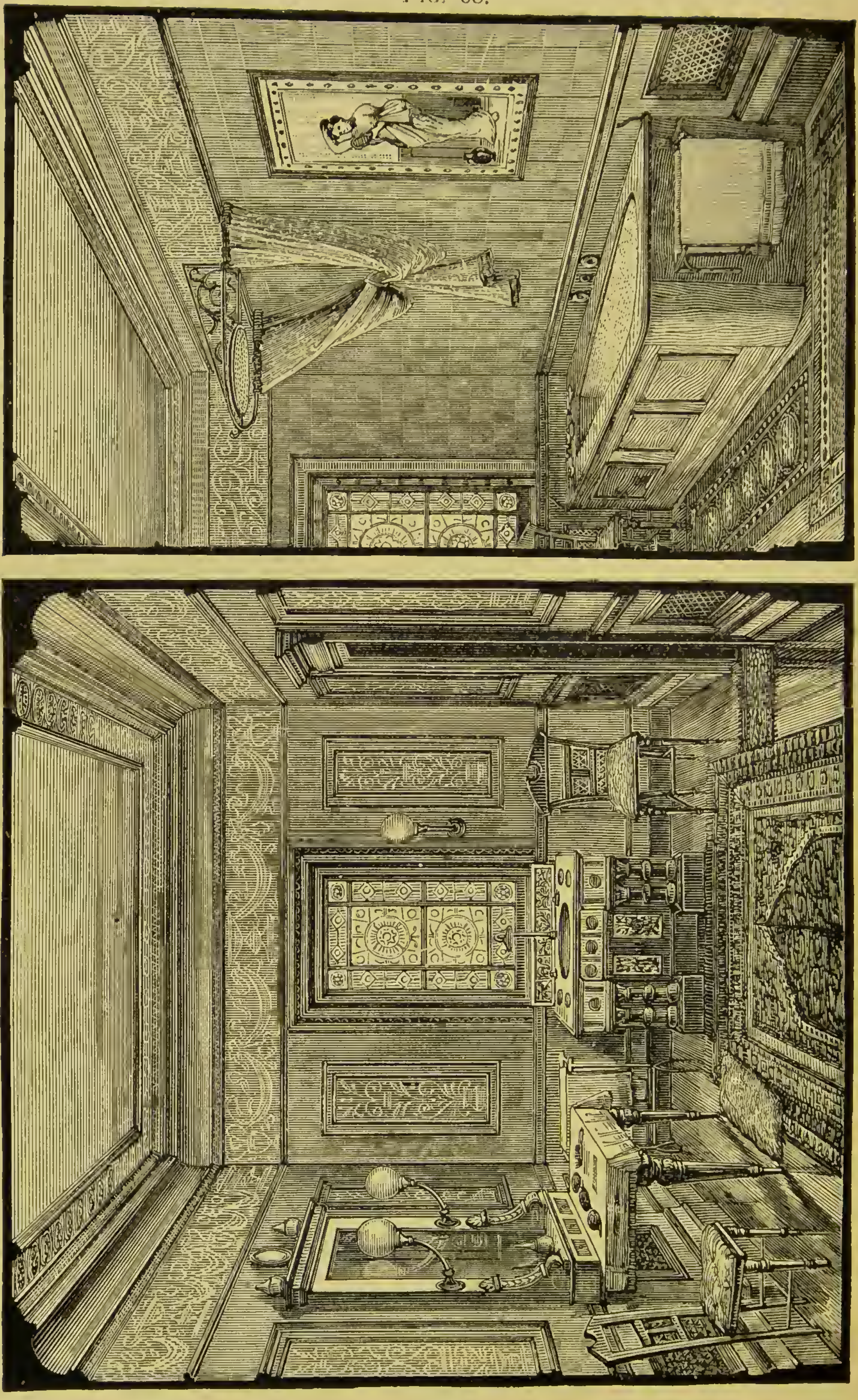
Fig. 59.



Special care must be taken with the waste and overflow that they should be of sufficient size—say 2 inches—the former to discharge its contents as quickly as possible, so as to ensure a good flush of the outlet pipe; and the latter, which may either be brought immediately into the open air through the nearest wall with a flap at its outer end, or connected with the waste pipe, which under any circumstances must be efficiently trapped and never connected directly with the soil pipe or sewer.

Jennings' invention for the combined discharged of waste and overflow is here shown (*see* Fig. 59) and is thus described. When the first water enters the bath all the dust and deposit left on the surface is carried with the water through the grating of the waste into the cylinder or chamber containing the discharge valve; as the water rises in the bath, so it rises in the cylinder until it reaches the top of the standing waste, which, as just stated, acts as an overflow. When the bath is to be emptied the hollow plug is raised, and the escape from the bath being perfectly free and of large capacity the deposit usually left on the sides and bottom of baths drained through a waste cock is altogether avoided.

Fig. 60.



XLVII.—LAVATORIES.—A room specially fitted up as a lavatory and bath-room, as suggested in the previous Section (XLVI), or as a lavatory simply, in town or country houses should be situated, if possible, on the ground floor, as such a position ensures to both occupier and guests a great saving of trouble.

In numerous instances lavatory apparatus, embracing a hot and cold water supply, may be readily adopted throughout the bed-rooms and dressing rooms of the upper floors of dwellings in the place of the jug and basin system, which is now so universal, and by its adoption not only may both time and trouble be saved to the occupants, but a large amount of unnecessary labour to the servants. These observations particularly apply where hot and cold baths are provided and are generally used.

Lavatory arrangements need never be unsightly in appearance. They more frequently partake of the happy combination of the useful and ornamental, and therefore can hardly ever be out of place; neither is it necessary to dwell much on the minor details connected with them, for so numerous are the designs, with so little difference in their main objects and characteristics, that it rests chiefly with the purchaser to make a selection suitable to his individual wants and to the distinguishing feature of the room in which they are to be placed. The apparatus may be fitted with either the tip-up or the ordinary plug basin, the former being generally preferred to the latter, because not only is the basin more quickly emptied but there is less chance of soap suds and other impurities being retained within it. The tip-up basin is, however, subject to the drawback, that owing to the sudden flush of water the trap beneath may become unsealed, and that the container too requires frequent cleaning.

The supply taps are of various sorts, and the most suitable are shown and described in Book II, Chapter XII, Section LXXXIX. Care must be taken in every case that the waste or outlet pipe is properly trapped in an accessible manner, and under no circumstance must it discharge directly with the soil pipe or sewer.

Fig. 61 shows one of the best of Doulton's lavatory-stands, arranged for the use of two persons, and suitable for any situation. It is fitted with tip-up basins, with both hot and cold supply, and is most simple in its valve arrangements. Ornamentation is not forgotten, and its price not being prohibitory, where general excellence is aimed at, it may with advantage be adopted in superior dwellings.

Fig. 62 shows another of Doulton's toilet lavatories on a somewhat smaller scale for the use of one person. It is most applicable for bed room use, and is fitted up with every convenience as in the previous example.

FIG. 61.

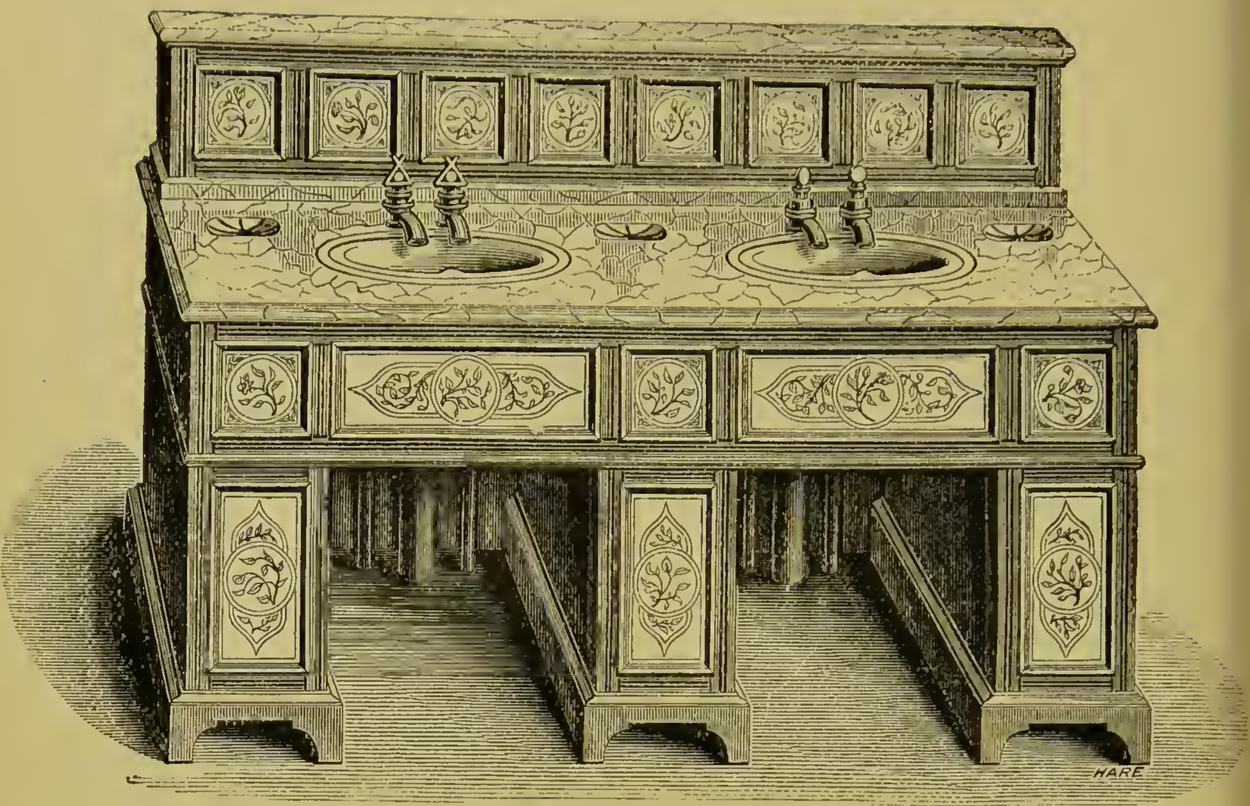
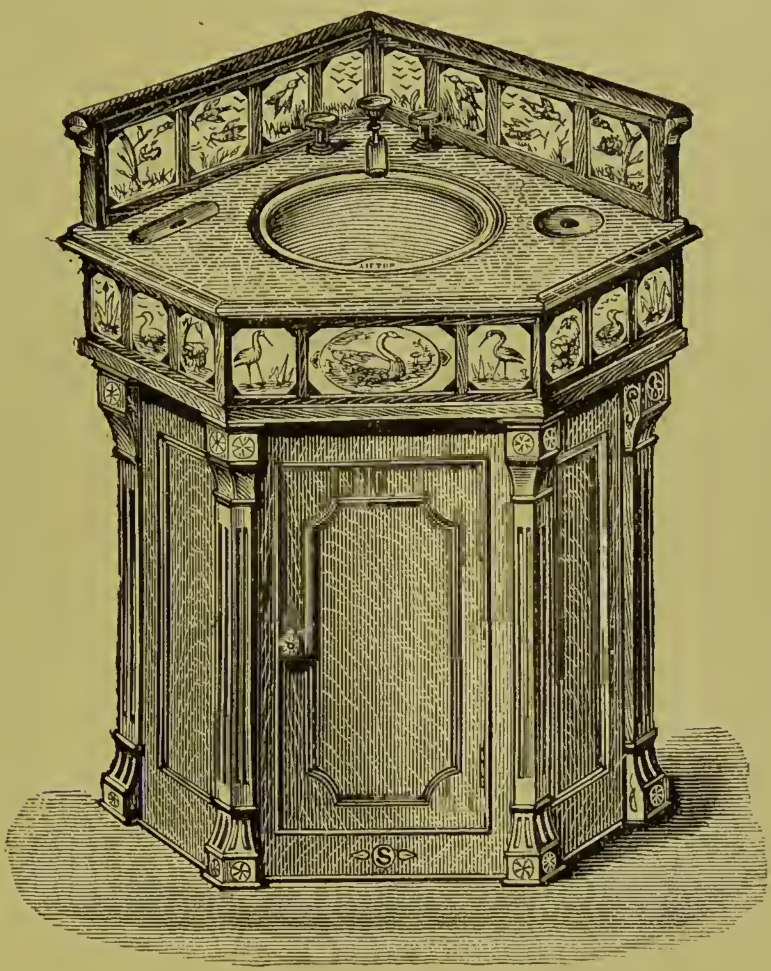



FIG. 62.

Fig. 63 shows a somewhat less pretentious angle tip-up lavatory by Stidder and Co., which may be taken as a fair example, both as

Fig. 63.



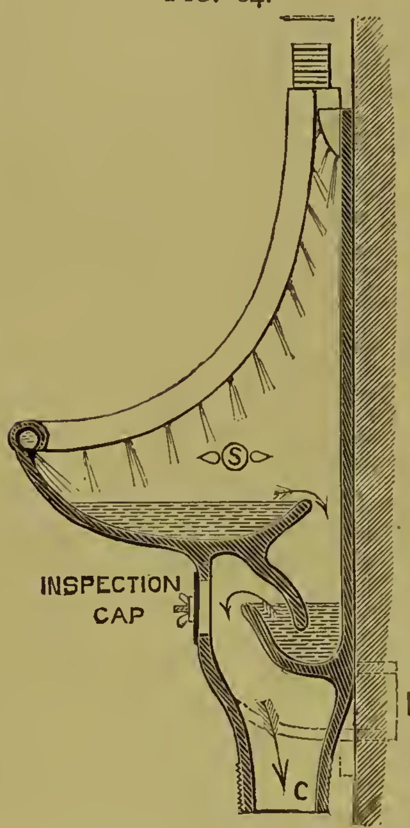
regards size and fittings, of what generally is requisite for billiard rooms, or passages in country houses.

The illustration (Fig. 60) which precedes this section shows a lavatory and bath-room combined. It is the arrangement of Messrs. Doulton and Co., who with several other firms of eminence have given special attention to lavatory appliances.

XLVIII.—Urinals.—A urinal should never be erected in a dwelling except under the following conditions:—(1.) That it is placed in a thoroughly retired position; (2.) That it is well ventilated, and has a plentiful supply of water for flushing purposes; and (3.) That its outlet should be thoroughly disconnected from the soil pipe or sewer. Failing any of these necessary requirements what may otherwise prove a great convenience is certain to become a positive nuisance.

Those to be preferred are made of glazed ware, either fixed above a treadle plate which when stood upon causes a flush of water to be poured into the basin from the supply-pipe above it, or below an apparatus, such as that of Jennings, automatically discharging its contents into the urinal at stated intervals; or they are provided with the necessary flush from a tap or valve over the basin, which has to be brought into action each time the urinal is used. The former plans are preferable as, owing to carelessness, the latter means of flushing is often overlooked, and the power of regulating an automatic flush by syphon or tip-over basin being well understood (*see* Chapter IV, Section XXXVII), there exists no reason why urinals should not always be automatically cleansed by periodical flushes without waste of water.

Fig. 64.



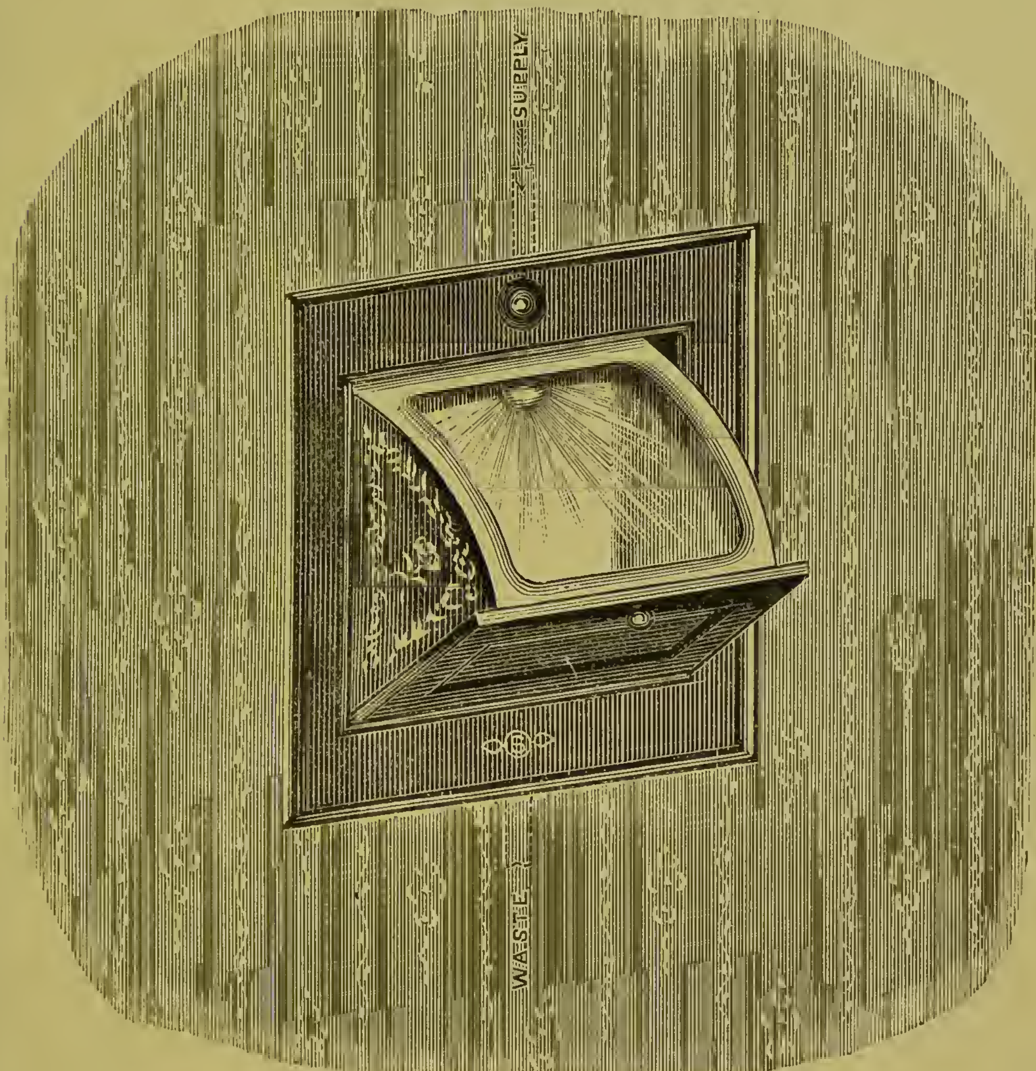

The name of Jennings is more associated with this description of sanitary appliance than that of any other individual, and some excellent specimens are known as his inventions. There are several other patentees, however, whose products are well known, and Fig. 64 shows Stidder's patent urinal which appears to be very suitable for private dwellings. In this invention there is always water to a depth of $1\frac{1}{2}$ inches in the basin which dilutes the urine and thus prevents corrosion in the waste pipe and trap. The trap, as will be seen, is an effective one, and is fitted with an inspection cap which is also useful for inspecting the waste pipe. With each flush of water not only is the basin flushed out and the water in it changed, but the water in the trap underneath is also renewed. This double protection, if aided by the ventilation of the pipe C, must prevent annoyance.

It may sometimes be necessary in offices and chambers to provide a urinal so contrived in shape as to be let into the wall of the room and thus to be hid from sight when not in actual use.

Fig. 65 illustrates a urinal of this description, ready for use. The flushing pan is at the back. It is made in the best Staffordshire pottery, and fixed to a mahogany door and frame. A plentiful supply of water is even more necessary in this case than in any other form of urinal, for without it a nuisance must speedily

arise. It should be noticed, too, as an additional reason for a copious supply of water, that there is no means of affording ventilation to the urinal when it is closed.

FIG. 65.



## CONTENTS OF CHAPTER VI.

### VENTILATION.



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# CHAPTER VI.

XLIX.—General Observations.—Enough has been said in previous sections to show that as the air incumbent upon a free and aërated soil in its natural condition is invariably pure and wholesome, it is the duty of the engineer to secure, by effective under-drainage, such a condition of the land upon which the dwelling stands as will ensure these advantages to its occupants.

In relation, however, to "ventilation" in its general application to the dwelling, the engineer's duty may perhaps be considered to end outside it, by the provision of external air answering to the attainable standard of 20·96 per cent. of oxygen, and ·04 per cent. of carbonic acid, leaving it to the architect in designing the rooms and passages within the dwelling to secure an internal condition of atmosphere in which the amount of carbonic acid shall not rise above ·06 per cent.

It can hardly be the province of the engineer to lay down any regulations for the guidance of the architect in the attainment of this object, though many of our most costly private and public buildings illustrate in a very conclusive manner how prejudicial to health is the disregard of such considerations. I except from this remark the ventilation of sewers, traps, soil-pipes, and other appurtenances to sewers, the proper working of which is particularly the duty of the engineer. As a general rule it may be stated that dwellings, built on a dry soil, which maintain in their several apartments the full amount of air required for animal respiration and the combustion of fuel used in each apartment—a condition generally gained by properly devised doors, windows, and fire-places—will maintain this standard without any special efforts at ventilation.

The maintenance of pure air within the apartments of the dwelling may generally be left to the natural laws governing temperature and the diffusion of gases; though, to avoid draughts, it is often necessary to raise by artificial means the tem-

perature of the in-coming air by admitting it through passages, or over surfaces which are heated, rather than directly from the open air. Richardson, who is an accepted authority on the subject, says: "In the ventilation and warming of a private dwelling, I would begin first with the staircase. This we ought to consider the principal artery of the house; and, if this were well warmed by a current of warm fresh air flowing into it, and a constant change effected by a ventilating outlet, warmed, so as to ensure its effective operation, a great part of the business would be effected, as the staircase would supply all rooms not in use with warm air in a sufficient degree, and would gradually ventilate the whole building, rendering it unnecessary to have further ventilation, except in the principal living and sleeping rooms of the family."

The following observations* on the heating of air and water will be found useful when devising arrangements for the warming of passages and staircases by pipes.

"In order to raise 1 lb. of water from 32° to 212°, the same quantity of heat is required as will raise 4 lbs. of atmospheric air the same number of degrees. So also, a pound of water in losing 1 degree would raise 4 lbs. of air 1 degree.

"On comparing equal volumes the result is more striking; water is 770 times heavier than air, and a cubic foot of water in losing 1 degree of temperature would raise $770 \times 4 = 3080$ cubic feet of air 1 degree.

"If we note the time required to raise water from the freezing to the boiling point, or from 32° to 212°, through an interval of 180°, and then note the time required to boil away the whole of the water, it will be found to be $5\frac{1}{2}$ times that of the former; that is, if it require five minutes to raise the thermometer 180°, or from freezing to boiling, it will require $27\frac{1}{2}$ minutes to boil away the whole of the water without any rise of temperature. It is obvious, therefore, that during this time the water in passing into steam must have absorbed $180° \times 5\frac{1}{2} = 990°$, which is the latent heat of steam.

"1 gallon of water converted into steam contains sufficient heat to raise $5\frac{1}{2}$ gallons from 32° to 212°. Hence, steam made to circulate in pipes through a building is an efficient and economical source of heat, 1 square foot of radiating surface in a steam pipe being, in general, sufficient for warming 200 cubic feet of space. No other vapour contains nearly so much latent heat as steam. A cubic inch of water at 212° becomes very nearly a cubic foot of steam at the same temperature, expanding as it does into 1696 times its volume."

The various contrivances which we see advertised for securing

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* *Warming and Ventilation*, by C. Tomlinson (Weale's Series).

what is rightly or wrongly termed "ventilation," are only useful when a sufficient provision of air space, and a proper provision of inlets and outlets in the shape of doors, windows, fire-places, flues, and shafts are wanting. Every day's experience, indeed, clearly proves that if we exclude from consideration the special appliances used with drainage and sewerage of dwellings, refinements of ventilation are quite out of place in well-planned private houses, and need only be resorted to where large numbers of persons congregate in special apartments or buildings, or where the arrangements of a dwelling are defective, or where accident has defeated a good design. Every apartment from cellar to attic in a private dwelling should command the necessary circulation of air without the existence of draughts, which are equally resisted by the poor in the cottage and the wealthy in the mansion. The rural labourer will stop up with a wisp of hay the best patent ventilator his landlord may introduce, if by atmospheric attraction cold air rushes in to take the place of warm, and it makes him feel cold; while the wealthy nobleman will simply vacate one apartment for another if he is made uncomfortable from the same cause.

Without trenching on the province of the architect, it may be useful here to give, in addition to what has been already said, some further information as to the space required for the maintenance of health within the dwelling. Some of the figures about to be quoted will not, however, accord with those already given, nor with each other, the only positive inference to be drawn from them being that in every living room there should be a constant but imperceptible change of *fresh* for *used* air, in quantity proportionate to the number, age, and occupation of the inmates. The engineer outside, and the architect inside, should make the requisite arrangements for securing this circulation in ordinary dwellings, while in the case of special buildings in which an extra number of people congregate, the ventilation should be placed in the hands of an expert who has devoted his attention to ventilation under every condition.

The number of respirations which men on an average take in a minute is stated to be 20, and the volume of air inhaled each inspiration is equal to 40 cubic inches, giving 800 cubic inches as the volume per minute which is expired from the lungs after use. (*Tredgold*). This volume is calculated by the same authority to render unfit for being breathed a much larger quantity of surrounding air. The atmosphere of a *lighted* room containing several persons is stated to be directly and indirectly vitiated to such an extent as to require a supply of fresh air equal to 4 cubic feet per minute for each individual in the room. This quantity, however, appears by the researches of Dr. Parkes, Dr. De Chaumont, and Dr. Angus Smith, to be altogether inadequate.

The cubical space considered to be necessary to afford dilution, and so correct the air-vitiation of public buildings, varies in a manner impossible to reconcile. For instance, the cubical space considered by high authority to be a right provision in the case of schools erected by the London School Board is 130 cubic feet per scholar; that for dormitories under the Metropolitan Lodging Houses Act is 240 cubic feet per head, while that allowed by the Poor Law Board is 300 cubic feet per head for healthy persons in workhouse dormitories. In English barracks the space considered to be right is 400 cubic feet per man in wooden huts, and 600 cubic feet in more substantial structures. Eight hundred cubic feet per head seems to be, however, the usual space required in middle-class houses; whilst in hospitals where, for obvious reasons, an increased space should be given, the allowance varies from 1,000 to 1,500 cubic feet per person. In the building of labourers' cottages on well-managed estates in this country, the recognized cubical space of living rooms is 1,200 feet, of parents' bedrooms 900, and of children's bedrooms 675 cubic feet.

Perhaps the most useful rules that can be recorded as to the quantity of external pure air which should pass per hour, per head, through a room, in order to keep down the carbonic acid to the accepted ratio already given, are those which are furnished by the late Dr. Parkes in his *Practical Hygiene*, in a table, from which the following figures are taken :—

| Amount of cubic space provided per person. | Amount of air necessary to dilute to a standard of ·06 per 100 (or ·04 C. acid and ·02 respiration) during the first hour. | Amount necessary to dilute to same standard after the first hour. |
|---|---|---|
| Cubic Feet. | Cubic Feet. | Cubic Feet. |
| 100 | 2,900 | 3,000 in each case. |
| 200 | 2,800 | |
| 300 | 2,700 | |
| 400 | 2,600 | |
| 500 | 2,500 | |
| 600 | 2,400 | |
| 1,000 | 2,000 | |

How is this mixture of fresh air with the vitiated air to be accomplished? Carbonic acid gas is heavier than atmospheric air, and expired air is rather lighter than the air of a room under ordinary conditions. This is due to the existence of nitrogen and vapour both of less specific gravity than air, and the higher temperature of the breath and the emanations of living bodies. These conditions give to vitiated air the buoyancy which takes it to the upper part or ceiling of a room, and point to the latter as the proper place for the outlet. The outer and cooler air, whether admitted from the open space surrounding the dwelling, or from

passages existing in it, should come in from a level as low as circumstances will admit without causing a draught, and to assist in the circulation and dilution of air, when doors, windows, and fire-places fail in that duty, it would appear desirable, as previously stated, to build in union with each stack of chimneys an air shaft (empty chimney) to serve the single purpose of ventilation. In this shaft valves specially arranged may be inserted to rid each chamber on the different floors of heated and vitiated air. The warmth of the air maintained in the shaft will assist the ventilation without risk of nuisance from smoke and dirt which so often attends the introduction of valves into chimneys, and as a general rule it may not be found necessary to adopt cowls of any kind, though one at the top of each of these shafts can do no harm and may do good.

Mr. Eassie, in his valuable treatise on *The Sanitary Arrangements in Dwellings*, relates a very interesting experiment made by Dr. Russell, of St. Bartholomew's Hospital, to ascertain the temperature of different parts of a room of which the doors and windows were of the ordinary kind. The experiment was tried with both doors and windows closed, and with a fire and three gas burners alight. The size of the room was 13 feet × $15\frac{1}{2}$ feet, and $10\frac{1}{2}$ feet high, and two persons only were in it, and this condition, it was assumed by Dr. Russell, was exactly the same as that of thousands of houses during the winter season. After three hours has elapsed the temperature at nine inches below the ceiling had risen $17\frac{1}{2}$ degrees; at 5 feet above the floor-line it had risen 15 degrees, while at the floor-line it was 4 degrees only above the temperature recorded before the doors and windows were shut, and when the room was filled with fresh air. From this it will be seen that in any arrangements made for the removal of vitiated air, and the admission of fresh air, it is necessary to have regard to the conditions which rule the temperature of the room.

The artificial supply of fresh air of a regulated temperature to, and the removal of vitiated air from, public buildings, such as hospitals and asylums, and of private mills and factories, and the dormitories of large institutions are, as already stated, objects of extreme difficulty. Up to this time science has certainly not been able fully to master the subject, although a great number of valuable theories have been propounded by experts, and ingenious inventions brought forward.

L.—Fresh Air Inlets and used Air Outlets (including Exhaust Cowls).—*Fresh Air Inlets.*—To secure a constant, equable, and regular supply of fresh air to the rooms of ordinary dwellings in sufficient quantity and without the creation of a draught, is an all important matter to the architect who realises his duties. Various have been the means attempted to achieve this end, when

ordinary means have failed, and various kinds of inlets, with and without flaps, valves, and other devices, have each in their turn been tried, though with no certainty of success.

A fresh air inlet, when it is intended to form a means of supply for the whole or principal part of a house, should, if possible, be fed from the basement with air unaffected by surrounding effluvia and dust; or if placed to do service at a higher level, should be connected with the central hall or corridor by means of a shaft. It should also be provided with valves so as to regulate the supply in accordance with the season. The fresh supply having been thus concentrated in the most suitable position in the dwelling it may, where deemed advisable, be made to pass over or through coils of hot water pipes, and having by this means been heated to a regular temperature, say 65°, may be diffused through all the living rooms of the dwelling.

When such a general system as this is aimed at, each room should have an inlet or inlets by means of specially made apertures. These apertures may be hidden from sight, but are essential to the general diffusion of fresh air. The well-known rule that fresh air should not be admitted at too low a level should never be departed from, for if it is, a sensible chilliness will be experienced by the inmates. It should always be remembered that there is no chance of the cool air, wherever admitted, passing directly out of the room by any apertures that may be available for its exit, for being naturally heavier than the warm air already in the apartment, it must fall, and be diffused generally.

It is also a matter of great importance that the main fresh air inlet to a dwelling should be sufficiently large to thoroughly answer its purpose.

Drs. Drysdale and Hayward say, on this point, "The primary inlet into the house for the fresh air must be sufficiently large to transmit an ample supply for the total wants of the house when it is put to its maximum of use. In such a house as we have supposed (*a good sized suburban villa*) it must be capable of giving passage to 8,087 cubic feet of air per minute, *i.e.*, 1,575 cubic feet for the occupants, 512 for the gas lights, and 6,000 for the fires (six living rooms at 800 cubic feet, and two bedrooms at 600 cubic feet each). In other words it should be capable of replenishing the whole house three times every hour."

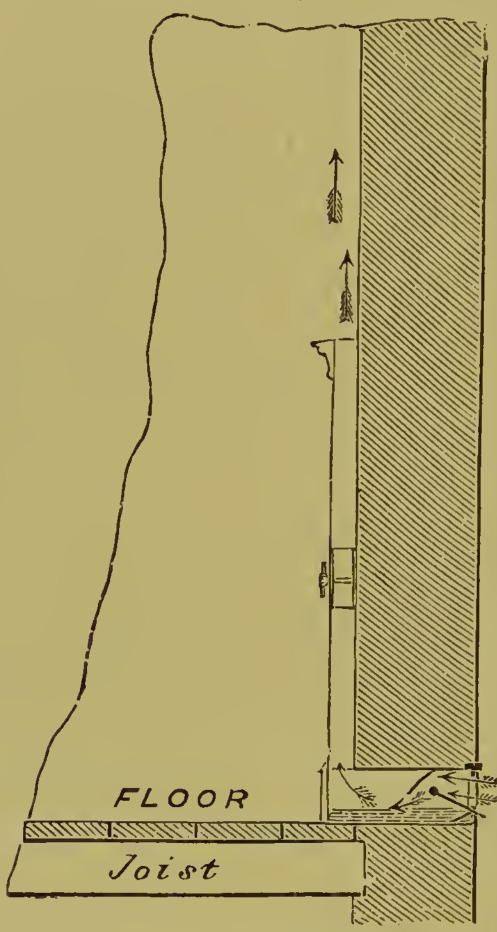
In cases where a general scheme of ventilation for the whole dwelling is impracticable, fresh air may be admitted into each separate apartment by apertures made in the outer walls at or near the floor level and connected with vertical tubes rising up the sides or angles of the room to a height a little above the heads of occupants when seated. It is there liberated and imperceptibly diffused through the room. Valves to regulate the

admission of the air, and which may be moved at will by the hand, should be provided to these tubes.

To obviate the objection caused in towns by the admission with the fresh air of dust and sooty matters, a regulated quantity of water may rest in a tray in the base of the tube, which is so shaped that the incoming air must pass in close proximity to the water. The dirt is absorbed by this water and not allowed to enter the room by the vertical tube, though the free passage of fresh air is in no way impeded.

Fig. 66 illustrates the method on a small scale, as carried out by the Sanitary Engineering and Ventilation Company, of Victoria Street, Westminster.

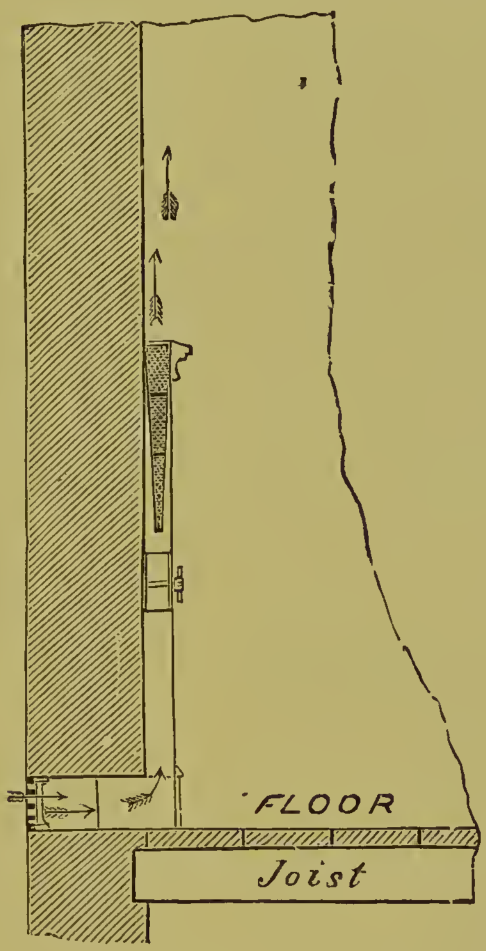
FIG. 66.




To keep these ventilators in perfect working order, the water in the tray of the box concealed in the wall should be replenished *once a week.* This may be done by pouring a large jug or can of water down the tube, taking care that the valve is open at the time; and access to the water box may be obtained from the outside, by turning back the hinged grating and lifting the front deflector plate, which is also hinged.

Fig. 67 shows another means for preventing the admission of blacks and other dirt. In this case cleansing bags of fine material, to which the impurities adhere, are suspended in the tubes. They should be drawn out from the top of the tube once a month and cleansed, to keep the tubes in perfect action.

FIG. 67.




The probability of this mode of ventilation coming into general use is much lessened by the necessity of frequent change and cleansing, which experience shows would involve neglect.

There are various more primitive means in extensive use for the admission of fresh air, such as the placing of a block of wood under the lower sash of the window, thus allowing fresh air to come in through the space left between the lower and upper sash, the cutting of circular holes in the woodwork of windows, care being taken to fill them with cotton wool so as to prevent the entrance of dirty floating substances; while various kinds of louvre ventilators of wood and glass may be found useful in individual cases.

*Used Air Outlets.*—Used air outlets for the discharge of vitiated air from the rooms of dwellings, when the ordinary chimney draught, and the accidental apertures of doors, windows, and floors are not sufficient to secure circulation, are generally placed near to or in the ceiling of the room to be ventilated.

It should be always borne in mind that with successful arrangements for the introduction of fresh air, there are many cases when a room may be well ventilated by the open fire grate alone, unassisted by any artificial means; and that where this has been proved insufficient there are various simple means which may rectify the fault without entailing any very great expense.

First should be noticed the invention of the late Dr. Arnott, called the Arnott Ventilator, which is a self-acting valve to be let into the chimney of the room to be ventilated so as to extract the foul air by means of the upward draught of the chimney.

Captain Galton, however, in speaking of it in his *Healthy Dwellings*, says that inasmuch as the number of cubic feet which can pass through the valve into the chimney per hour is very limited, this form of ventilator is not adapted to be the only outlet for any room with several people in it. It is, moreover, subject to the objection that it affords a ready passage into the room, upon a change of draught, for dirt and dust, which in time mark the ceiling and the wall in such a manner as to cause a disfigure-

FIG. 68.

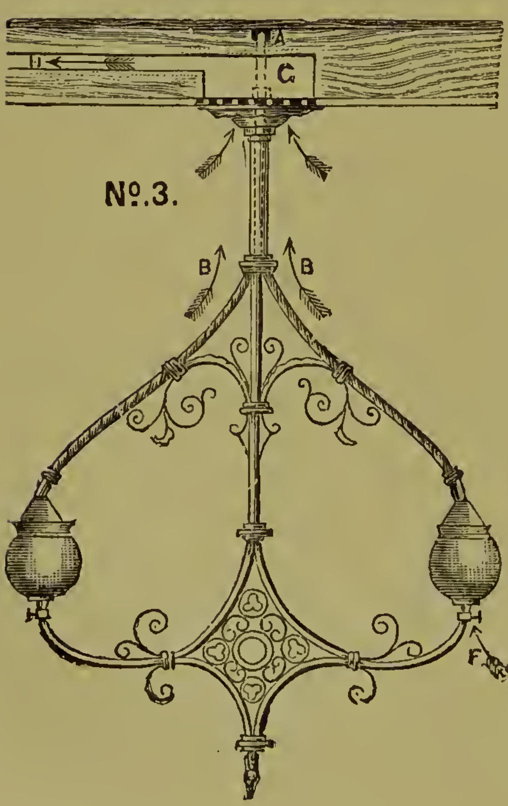
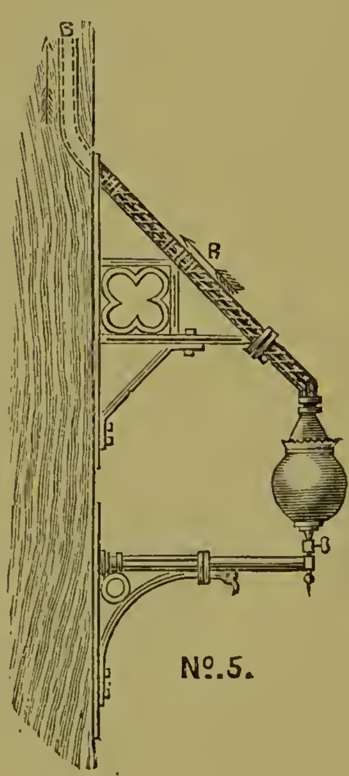



FIG. 69.



ment, which it is hardly possible by any preventive measures to arrest.

In rooms where there are many occupants, or where much gas is used, as in dining, billiard, and smoking rooms, it has been desirable to ventilate them, and to carry off the fumes of the gas at the same time. This in many instances may be favourably done in moderate sized dwellings by means of special tubes, as shown by Figs. 68 and 69, connected with a shaft of the description suggested in Section XXV, or by direct communication with the open air by passage between ceiling and floor above.

Mr. Boyle, of the Holborn Viaduct, advocates a very perfect system of tubes throughout the whole house, with special means for the admission of fresh and the discharge of used air. His system of tubes are in certain instances associated with artificial heating, whereby the incoming fresh air is warmed, and a more perfect circulation maintained. In large establishments, both public and private, such an arrangement may be found very desirable.

A special flue, if reserved solely for ventilation, with valves to facilitate the discharge of used air into it, is naturally free from the objection raised in a previous paragraph to chimneys used for the same purpose. Automatic valves are often found very necessary in connection with used air outlets when they discharge directly into the open air, for if they are not adopted, the "outlets" are sure at one time or another to become inlets, and prove sources of annoyance. Unlike the system advocated by Boyle, who, as explained, takes the used air by separate channels up to the roof of the house, there to be drawn out by exhaust cowls, Drs. Drysdale and Hayward have laid it down that it is necessary to concentrate the tributary tubes by separate courses at one point at the top of the house, so as not to allow them to enter the exhaust shaft at the various floor levels. They give the following reasons for this necessity. They say "there is the danger that the foul air may be drawn from one room into another; and besides this, when several flues (tubes) enter one common shaft at different levels the draught is so interfered with that it becomes quite irregular and uncertain, some of the flues (tubes) receiving more than their proper share of the suction, whilst others receive little or none. Hence it is absolutely necessary that all the flues (tubes) of the house, shall be conducted separately to above the level of the ceiling of the top room, and then be carried down again by one common syphon flue (tube) to the bottom of the kitchen chimney shaft, so that the full suction power may act upon them all."

It is not, however, proposed in this work to dwell in detail upon any special arrangements of extensive ventilation; for this should be the work of experts, inasmuch as it is generally unnecessary in ordinary dwellings, and the aid of experts who have made it

the special subject of their lives has to be sought when any such scheme is specially desired.

*Exhaust Cowls.*—So numerous are the varieties (with so little difference between them) of cowls now before the public, both rotatory and stationary—most of which have been treated in detail by the various sanitarians who have written on the subject, that it is only here proposed to refer to a few of the best known, whose simplicity should command attention. An opinion which appears to be well founded is gradually gaining ground that stationary cowls possess one great advantage over rotatory ones in that the motion of the latter is liable to be impeded by the corrosion consequent on exposure to the weather, and that, therefore, when they are adopted, periodical inspection becomes a matter of necessity. This corrosion is sometimes rapid in cowls placed over soil pipes. Among rotatory ventilators should be noticed Banner's cowl, Howarth's archimedean screw, and the empress cowl.

FIG. 70.

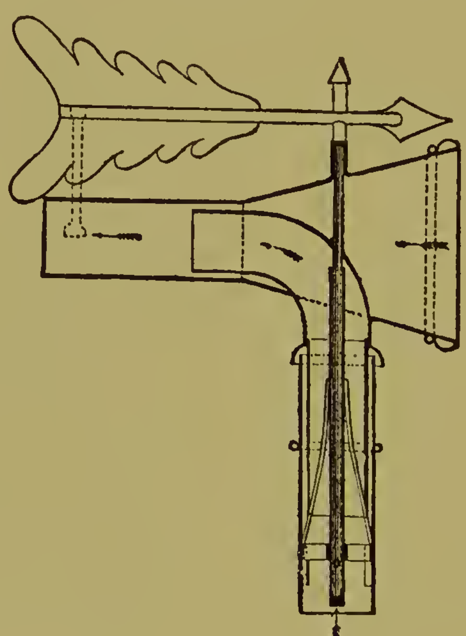
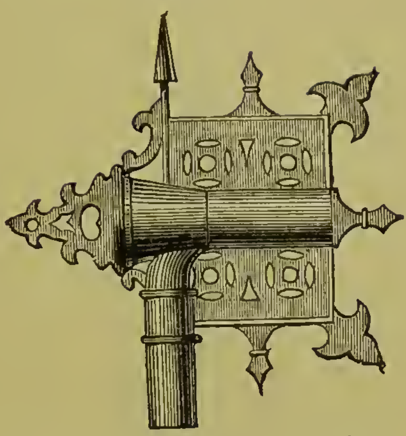


Fig. 70 represents Banner's rotatory cowl, which is undoubtedly the best of its class. In this cowl, experience has shown that the drawback just referred to, as inherent in revolving cowls, can to a great extent be overcome by means of lubrication, and that it can be made to act for years without derangement. Its appearance may be made ornamental (*see* Fig. 71), and its action is thus described. "The large end of a funnel shaped tube is always directed towards the wind, and a current of air passing in there is pressed forward through the annular space between the two cylinders. When it

reaches the end of the inner one it expands round it, and in its passage out at the smaller end, a vacuum is created round the point of the inner cylinder, which by suction draws out its contents into the outer air.

FIG. 71.



The empress cowl, now in common use, is designed to secure an up-draught action of the combination of a vertical louvre cover revolving with an internal archimedean screw.

Among the best stationary exhaust cowls should be noticed Boyle's patent air pump ventilator—a small specimen of which is illustrated by Fig. 72, Hellyer's exhaust cowl (*see* Fig. 73), Banner's cowl (*see* Fig. 74), Buchan's cowl (*see* Fig. 75), and the cowl of the Sanitary Engineering and Ventilation Company (*see* Fig. 76).

FIG. 72.

FIG. 73.

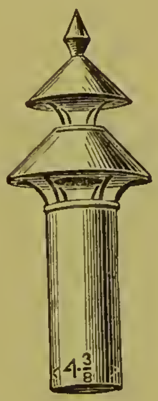
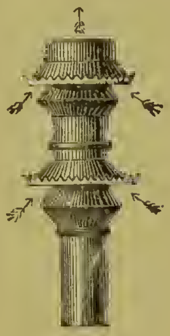



FIG. 74.



These several cowls, though differing in their form, all aim at the same object—the extraction of the air or vapour it is desired to discharge, by means of a cross horizontal draught acting upon the vertically uprising air or vapour, without the possibility of a down-draught.

The air pump ventilator (Fig. 72), the inventor says, consists of four sections (*see* Fig. 77), each acting independently of the other: 1 shows a curved baffle plate or guard to concentrate the current, and prevent the wind blowing through the slits opposite; 2 a curved plate to take the pressure off the vertical slits communicating with the internal chambers, and to prevent down-draught. The external air impinging on the diaphragm 3 is deflected on to the central radial plate 4, creating an induced current, and in its

Fig. 75.

Fig. 76.

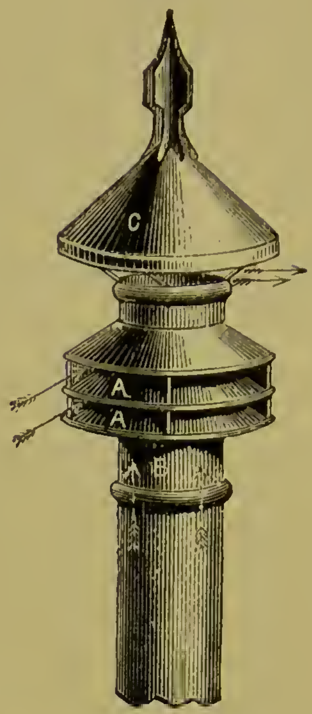
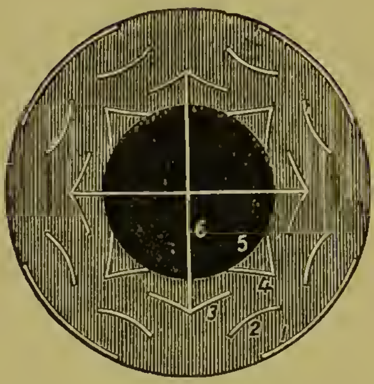



Fig. 77.




passage drawing the air from the vertical chamber 5, expelling it at the opposite opening. The foul air immediately rushes up the shaft connecting the ventilator with the apartment being ventilated to supply the place of the air extracted, thus securing a continuous and powerful upward current; 6 represents the partitions separating the chambers and preventing external air being drawn through the slits upon which the wind is not directly acting.

The inventor says further, that the ventilators are continuous in their action, and, being self-acting in every part, require no attention. That by effectually extracting the hot vitiated air as it is generated, the place is always kept pure and sweet—the supply of fresh air being admitted through louvre gratings or vertical tubes in the lower parts of the building. That there is no perceptible

current in the place being ventilated, whilst the atmosphere is being continually changed. That they are entirely free from down-draught.

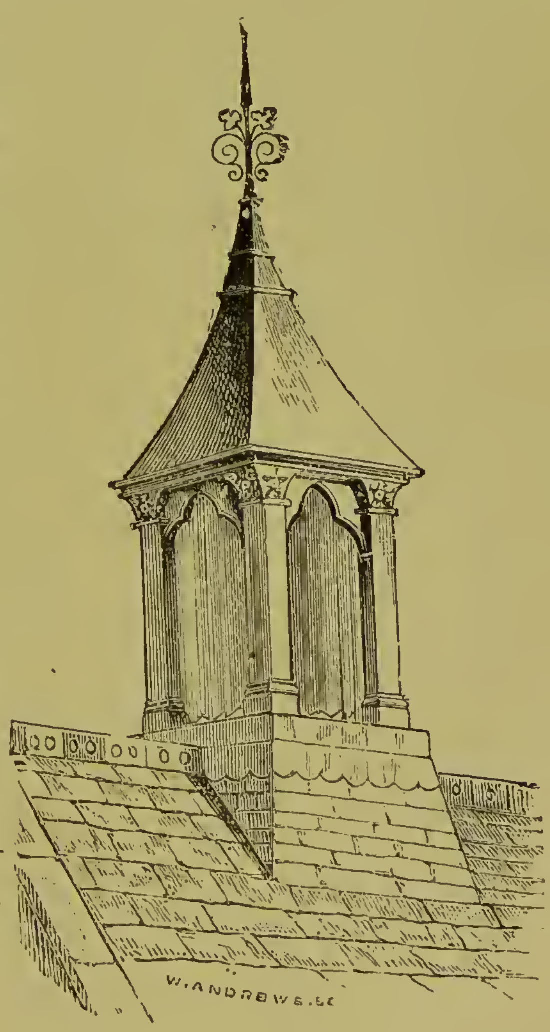
Mr. Hellyer, speaking of cowls generally, says that he had considered plain caps quite sufficient for fixing on the tops of ventilating pipes, to waste pipes, and soil pipes. He now, however, considers that cowls should be fixed on all ventilating pipes for foul air, not so much for assisting the up-draught, as for preventing the down-draught; adding that the tests which had been instituted showed that the palm of victory must be given to Mr. Buchan's, Fig. 75, whilst the results warranted him (Mr. Hellyer) placing his own, Fig. 73, second in the list.

Mr. Banner states that the principle upon which his cowl is constructed, as shown by Fig. 74, secures a continuous suctional draught across the shaft under all the varying influences of wind and weather. The Ventilation Company describe their fixed exhaust ventilator, Fig. 76, in the following terms:—

The arrangement of the coned plates, AA, is such that the air currents acting upon them create a partial vacuum in the tube B, which has the effect of sucking out the air from the apartment with which it is connected, as indicated by the arrows; and the cap C is so arranged that, at whatever angle the wind strikes the ventilator, there is no possibility of down-blow.

It may be concluded that cowls are not generally necessary, though under certain conditions they may be favourably applied. They allow of sufficient ornamentation to be relieved of objection on the score of unsightliness, and when they can be fixed upon the roofs of dwellings, they may, in fact, be made to add to the general good effect of the structure. Fig. 78 exemplifies a large ornamental cowl by Messrs. Boyle.

FIG. 78.



# WATER.

## BOOK II.

### CONTENTS OF CHAPTER VII.

#### WATER CHEMICALLY AND PHYSICALLY CONSIDERED.



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## CHAPTER VII.

LI.—Water in relation to the Dwelling.—A copious supply of pure water is quite as important a consideration in the sanitation of the dwelling as the maintenance of pure air, for the evil effects of water impurity are as widespread and as positive. This fact demands at the hands of householders the greatest attention, because, as the chemist has shown, it frequently happens that the waters most acceptable to sight and palate are injurious to health.

To the use of impure water may be traced cholera, dysentery, diarrhœa, entozoa, malarious fevers, and other zymotic diseases, which it would appear are only, in a great measure, to be pre-

vented by the avoidance altogether of waters flowing from naturally corrupt or polluted sources. It is, in fact, only in those instances where pure water has been rendered impure by the contamination due to storage that precautionary or remedial measures can be taken with good and certain effect.

In cases where there is a constant supply of water from a pure and "wholesome" source without storage, the inmates of dwellings within a district so served, are, as a rule, free from the ills referred to; whilst in cases of an intermittent public supply, or where private wells are used or rain water collected for domestic purposes without subsequent filtration those evils are frequent.

It is, indeed, satisfactory to be able to affirm that it is within the power of all owners of houses, having at their command water from a pure source, but to collect which for distribution and use storage has to be resorted to, to counteract at a moderate cost the evils resulting from such storage.

LII.—Constituents of Normal Water.—Water in its normal state consists of only two elements, hydrogen* and oxygen, in the proportion of two volumes of the former gas to one of the latter, or by weight 11·11 per cent. of hydrogen to 88·88 per cent. of oxygen.

In water the two gases of which this substance is composed are chemically combined, and, unlike the constituents of air, which remain unaltered, they lose their gaseous form and their distinctive properties, both physical and chemical, and become a new substance.

LIII.—Of Foreign Polluting Matters.—Water is, however, no sooner in existence than it loses its normal condition by the absorption of foreign matters with which it comes in contact, and which detract from its purity. This depreciation takes place in its first condition as the vapour of the atmosphere; then as that vapour changes into rain and falls to the ground; then as the collected rain passes over the surface of the earth on its way to the rivers, or, if absorbed, as it percolates through the soil to the subterranean water levels beneath; then as it passes through the earth to find outlet at the surface in the beds of rivers and streams, or at impervious outcrops in the shape of springs; and lastly, as it is discharged to the sea after it has assumed the form of rivers and tributary streams.

In its condition as vapour and as rain, water is defiled by the gases of putrefying organic matters, which rise into the air from the surface of the earth, while as dew and hoar-frost it is

* Hydrogen is a colourless, tastelessness, and inodorous gas, 14½ times lighter than atmospheric air. It is very inflammable, and burns in air with a pale flame, producing water by combining with atmospheric oxygen.

affected by the same causes only in a greater degree. As vapour and rain too, water is also rendered impure by smoke from burning, and by emanations from mineral substances used in manufacture; as collected rain passing over impervious surfaces towards the rivers and their tributaries, water gathers those organic and inorganic impurities which are more or less associated with cultivated and uncultivated lands, and with sparsely populated as well as closely populated districts; and when percolating and travelling through the earth, water mixes with any organic matter that may have already found its way into the ground from the surface, while its chemical qualities are profoundly influenced by the character of the geological formations through which it passes, and by its mixture with salts and dissolved substances existing in the earth.*

When the rain after accumulating in the bowels of the earth has found outlet in springs, and has taken the shape of rivers and streams, it is further polluted by the influx of the excrements of animals, and the liquid refuse of all kinds from human habitations in consequence of those rivers and streams acting as natural drains for the districts through which they flow. Moreover, water when utilized may be affected, and often is affected, by the materials of which tanks, cisterns, and delivering conduits are composed, and the way in which the last are jointed.

LIV.—Primary Source of Supply. Yearly and Monthly Rainfall.—The quantity of water placed at the disposal of man may be stated to depend, primarily upon the amount of rainfall, and, secondarily, upon the quantity thrown off the surface after satisfying vegetation—which is available for storage above ground—and the quantity absorbed by porous

---

* "The influence of geological formation upon the palatability and wholesomeness of *surface water* is often inconsiderable, owing to the deposit of peaty matters upon the surfaces of the rocks and soils—unpolluted surface waters from the most widely different geological formations differing but little in the proportions of organic matter which they contain; but where the water percolates or soaks through great thicknesses of rock, its quality, when it subsequently appears as *spring or deep well water*, depends greatly upon the chemical character of the material through which it has passed. When the formation contains much soluble saline matter the water becomes loaded with mineral impurities, as is frequently the case when it percolates through certain of the carboniferous rocks, the lias and the saliferous marls. When the rock is much fissured or permeated by caverns or passages, like the mountain limestone, for instance, the effluent water differs but little from surface drainage, and retains most of the organic impurities with which it was originally charged.

"But when it is uniformly porous like the chalk, oolite, greensand, or new red sandstone, the organic matter at first present in the water is gradually oxidized and transformed into innocuous mineral compounds."

surfaces after satisfying both vegetation and evaporation—by which nature's underground storage is maintained.

The rain falling in different countries and places varies very greatly in quantity, in season, and in the circumstances which would influence its collection, conservation, and use.

| | | |
|---|---|---|
| At Cracow the annual fall is ... | Europe | $13\frac{1}{3}$ inches. |
| „ Brussels „ „ ... | | $28\frac{1}{2}$ „ |
| „ Rome „ „ ... | | 31 „ |
| At Calcutta „ „ ... | Asia | $76\frac{1}{2}$ „ |
| „ Bombay „ „ ... | | $75\frac{1}{6}$ „ |
| At Washington „ „ ... | America | $41\frac{1}{6}$ „ |
| „ Charleston „ „ ... | | 54 „ |

For our present object it will suffice if I limit my observations to the annual depth of rain falling upon the surface of England and Wales. It averages 32 inches.—*Symons.*

In England the average monthy rainfalls on the two sides of the country, east and west, will be found to closely approximate those given in the following tabular statement, taken from *The Farm Homesteads of England*:—

WESTERN SIDE OF ENGLAND.

| | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sep. | Oct. | Nov. | Dec. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ins. | Ins. | Ins. | Ins. | Ins. | Ins. | Ins. | Ins. | Ins. | Ins. | Ins. | Ins. | Ins. |
| Keswick ... | 4·87 | 2·63 | 4·60 | 4·24 | 3·02 | 4·12 | 4·94 | 5·85 | 4·41 | 9·00 | 8·35 | 6·66 | 62·69 |
| Lancaster | 3·46 | 2·99 | 1·75 | 2·18 | 2·46 | 2·51 | 4·14 | 4·58 | 3·75 | 4·15 | 3·75 | 3·95 | 39·67 |
| Manchester | 2·31 | 2·56 | 2·09 | 2·01 | 2·90 | 2 50 | 3·69 | 3·66 | 3·28 | 3·92 | 3.36 | 3·83 | 36·11 |
| Exeter ... | 3·32 | 2·35 | 2·34 | 1·97 | 2·14 | 2·26 | 1·91 | 2·59 | 2·60 | 3·69 | 4·67 | 2·74 | 32·58 |
| Truro ... | 4·66 | 3·79 | 3·44 | 2·54 | 2·41 | 2·79 | 2·64 | 3·04 | 3·68 | 4·08 | 6·11 | 4.90 | 44·08 |

EASTERN SIDE OF ENGLAND.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| York ... | 1·72 | 1·02 | 1·19 | 1·50 | 1·41 | 2·35 | 2·65 | 2·93 | 2·08 | 2·09 | 1·75 | 1·31 | 22·00 |
| Boston ... | 1·59 | 1·45 | 1·52. | 1·50 | 2·17 | 2·41 | 2·77 | 2·83 | 2·24 | 2·72 | 2·26 | 1·44 | 24·90 |
| Norwich ... | 1·97 | 1·45 | 1·16 | 1·79 | 1·91 | 1·77 | 3·10 | 2·76 | 2·48 | 2·94 | 3·02 | 1·74 | 26·09 |
| Chiswick ... | 1·95 | 1·66 | 1·43 | 1·40 | 1·85 | 1·79 | 2·05 | 2·75 | 2·37 | 2·92 | 2·70 | 1·53 | 24·40 |
| Cobham ... | 2·24 | 2·38 | 1·72 | 1·21 | 3·19 | 1·44 | 2·27 | 2·93 | 3·57 | 2·88 | 4·41 | 1·96 | 30·20 |

In the higher grounds of the west, the annual depth ranges from 30 to 75 inches, while in the flatter lands of the east it varies from 17 to 35 inches. The total quantity of rain which falls on an average of years on the surface of England and Wales amounts to 27,019,632,000,000 gallons. This gives an average covering

of 723,904 gallons to an acre of surface.* Of course these figures do not afford any very tangible data for practice, as each requirement must stand on its own merits, but they give evidence of the ample scope which is at the engineer's command for providing a supply of water for all purposes.

They show that each acre of surface, even in the eastern districts of England, where the average rainfall does not exceed half that of the western districts, receives as rain nearly 80 times as much water as an average member of the population requires.

At Greenwich, where reliable gauging has been adopted since 1815, the annual average from that date has been 25·36 inches, the maximum reaching (1824) 36·3 inches, and the minimum falling to 16·8 inches. The maximum is generally estimated by engineers to be one-third in excess of the average rainfall, and the minimum one-third below it.

Mr. George Dines, the well-known builder of Pimlico, some few years ago prepared some very interesting diagrams and tables showing the rainfall in the metropolis during a period of 60 years, and the mean quantity of rain due to each month. The result places the different months in the following order, and I have added for comparison the monthly rainfall of the eastern and western sides of England:

| 1813—72. | Rainfall in Metropolis. | Average Rainfall of the East and West Sides of England. | | 1813—72. | Rainfall in Metropolis. | Average Rainfall of the East and West Sides of England. | |
|---|---|---|---|---|---|---|---|
| | | East. | West. | | | East. | West. |
| | Ins. | Ins. | Ins. | | Ins. | Ins. | Ins. |
| October ... ... | 2·74 | 2·71 | 4·97 | December ... | 1·93 | 1·60 | 4·42 |
| September ... | 2·35 | 2·55 | 3·54 | January ... | 1·91 | 1·89 | 3·72 |
| July ... ... | 2·32 | 2·57 | 3·46 | April ... ... | 1·66 | 1·48 | 2·59 |
| November ... | 2·28 | 2·83 | 5·25 | March ... ... | 1·52 | 1·40 | 2·84 |
| August ... ... | 2·26 | 2·84 | 3·95 | February ... | 1·50 | 1·59 | 2·86 |
| May .. ... | 2·07 | 2·11 | 2·59 | | | | |
| June ... ... | 2·01 | 1·95 | 2·84 | | 24·55 | 25·52 | 43·03 |

From these figures it will be seen that the wettest months of the year in London are September, October, July, and November, and that there is only some slight difference in this particular between London and the rest of the country. With the exception of July these months occur when summer is on the close, when vegetation no longer requires the same support of moisture as

* An inch of rain falling on an acre gives 22,622 gallons of water; and if 12 inches only be collected, a supply will be gained from a single acre sufficient to satisfy 30 persons all the year round with 25 gallons of water each daily.

previously, and when evaporation necessarily becomes less active with increased moisture and reduced temperature. It is when such conditions prevail that the larger proportion of the rainfall is rendered available for use by storage above ground if collected from saturated and impervious surfaces, or serves to replenish the subterranean supply which nature stores under our feet in the water-bearing strata.

It will be found that, in accordance with the amount of the winter's rainfall, especially that of the months of September, October, and November, so will the following summer's subterranean supply be decreased or increased in some measure by the amount of the rainfall of the antecedent winter. If, for instance, two dry winters succeed each other the drought of the following summer will be proportionately increased. The following tabular statement shows the relative quantities of rain that fell in winter and summer during six years of the period just instanced.

| | 1867-8. | | 1868-9. | | 1869-70. | | 1870-1. | | 1871-2. | | 1872-3. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Winter—Oct. to March inclusive. | Summer—April to Sept. inclusive. | Winter—Oct. to March inclusive. | Summer—April to Sept. inclusive. | Winter—Oct. to March inclusive. | Summer—April to Sept. inclusive. | Winter—Oct. to March inclusive. | Summer—April to Sept. inclusive. | Winter—Oct. to March inclusive. | Summer—April to Sept. inclusive. | Winter—Oct. to March inclusive. | Summer—April to Sept. inclusive. |
| | Ins. | Ins. | Ins. | Ins. | Ins. | Ins. | Ins. | Ins. | Ins. | Ins. | Ins. | Ins. |
| East ... ... | 10·80 | 8·33 | 16·17 | 12·76 | 12·81 | 8·01 | 13·92 | 14·41 | 10·45 | 16·61 | 15·79 | 10·68 |
| South ... ... | 13·39 | 12·92 | 17·69 | 12·47 | 13·47 | 5·51 | 15·76 | 19·30 | 20·94 | 16·23 | 27·48 | 10·46 |
| West ... ... | 18·50 | 13·61 | 26·58 | 16·47 | 17·09 | 10·47 | 17·42 | 19·40 | 19·31 | 24·32 | 22·04 | 16·95 |
| North ... ... | 10·10 | 9·85 | 16·09 | 10·77 | 12·72 | 7·46 | 16·42 | 18·64 | 14·60 | 21·43 | 19·57 | 11·92 |
| Mean of wintr. | 13·20 | — | 19·13 | — | 14·02 | — | 15·88 | — | 16·32 | — | 21·22 | — |
| Mean of sumr. | — | 11·18 | — | 13·12 | — | 7·86 | — | 17·94 | — | 19·65 | — | 12·50 |
| Year ... ... | 24·38 | | 32·25 | | 21·88 | | 33·82 | | 35·97 | | 33·72 | |

Average of the six years, 30·34 inches.

LV.—Infiltration of Rain by Absorbent Soils in Summer and Winter for the Maintenance of Rivers, Springs, and Subterranean Supplies.—The proportion of the rainfall absorbed by and penetrating a porous surface to maintain the river systems varies considerably. On an average of years we find that from one-fourth to one-third of the rainfall, according to the nature of the soil and state of husbandry, thus descends to the subterranean levels. The quantity which infiltrated the chalk district in the neighbourhood of King's Langley to replenish the springs and rivers of that neighbourhood, was ascertained and recorded by the late Mr. Dickinson, the well-known paper maker of King's

Langley and Hemel Hempstead, up to the time of his death, by means of a gauge devised by Dalton, of Manchester. The records have been continued from that date by his successor, Mr. Evans, a late President of the Geological Society. The gauge is fixed in the ground three feet below the surface, and not only is the quantity of rain that finds its way down to it indicated, but, by deducting that quantity from that which falls on the surface, and which is carefully gauged and recorded, the observer may ascertain the amount of water evaporated.

The following table gives the rainfall and percolation (through Dalton's gauge, filled with surface soil) at Nash Mills, Hertfordshire, from the year 1835 to 1860:—

| Year. | Winter. | | Summer. | |
|---|---|---|---|---|
| | Rainfall. | Percolation. | Rainfall. | Percolation. |
| | Ins. | Ins. | Ins. | Ins. |
| 1835–6 ... ... ... | 16·39 | 14·27 | 12·20 | 2·10 |
| 1836–7 ... ... ... | 16·71 | 13·81 | 9·80 | ·10 |
| 1837–8 ... ... ... | 9·81 | 5·45 | 10·81 | ·10 |
| 1838–9 ... ... .. | 12·58 | 8·59 | 17·41 | 2·60 |
| 1839–40... ... ... | 14·71 | 12·59 | 9·68 | — |
| 1840–1 ... ... ... | 10·32 | 3·10 | 16·95 | — |
| 1841–2 ... ... ... | 16·56 | 17·98 | 12·15 | 1·30 |
| 1842–3 ... ... .. | 13·46 | 9·34 | 14·04 | ·99 |
| 1843–4 ... ... ... | 15·41 | 8·86 | 8·07 | — |
| 1844–5 ... ... ... | 13·11 | 7·10 | 11·57 | — |
| 1845–6 ... ... ... | 13.93 | 9·01 | 11·50 | ·28 |
| 1846–7 .. ... ... | 12·93 | 5·84 | 11·31 | — |
| 1847–8 ... ... ... | 15·84 | 8·94 | 13·00 | ·70 |
| 1848–9 ... ... ... | 13·49 | 6·22 | 13·91 | — |
| 1849–50... ... ... | 8·58 | 1·44 | 11·82 | — |
| 1850–1 ... ... ... | 14·71 | 8·49 | 9·25 | ·04 |

| Year. | Winter. | | Summer. | |
|---|---|---|---|---|
| | Rainfall. | Percolation. | Rainfall. | Percolation. |
| | Ins. | Ins. | Ins. | Ins. |
| 1851–2... ... ... | 10·75 | 3·66 | 19·97 | 1·50 |
| 1852–3... ... ... | 20·27 | 10·74 | 16·79 | 24 |
| 1853–4... ... ... | 9·66 | 4·22 | 9 47 | — |
| 1854–5... ... ... | 9·32 | 2·45 | 12·66 | ·19 |
| 1855–6... ... ... | 14·48 | 6·82 | 14·86 | 2·79 |
| 1856–7... ... ... | 11·96 | 3·72 | 14·11 | 1·11 |
| 1857–8... ... ... | 11·81 | 5.64 | 12·27 | ·80 |
| 1858–9... ... ... | 9·64 | ·09 | 18·31 | — |
| 1859–60 ... ... | 16·49 | 9·27 | 20·40 | 3·16 |
| Average 25 years | 13·317 | 7·506 | 13·292 | ·721 |
| Difference—evaporated or lost | 5·811 | | 12·571 | |

| | |
|---|---|
| Total average rainfall ... ... ... ... ... ... | 26·609 inches. |
| Percolation ... ... ... ... ... ... ... | 8·227 ,, |
| Difference—evaporated or lost ... ... ... ... | 18·382 |

LVI.—Quantity or Proportion of Rainfall evaporated from Absorbent or Non-Absorbent Surfaces and so lost for Supply.—The difference between the amount of rainfall and percolation given in the foregoing table represents, as I have stated, the amount of rain lost each year by evaporation, including the small proportion which, with undisturbed soils, would overflow even a porous surface at times of extreme downfalls of rain, when the rapidity of descent will prevent absorption. For practical purposes we may assume that from 17 to 22 inches are lost by evaporation from the porous surfaces of this country.

The proportion of rainfall evaporated and "lost" from non-porous surfaces is quite another matter, and I am not in pos-

session of any data by which to give the amount. Engineers are accustomed to adopt arbitrary rules of their own—modified by the circumstances, physical and meteorological, of each case—when they desire to arrive at the net quantity of water which can be collected from various gathering grounds, and there is ample reason for the practice. Mr. Bateman, C.E., states the loss by evaporation to vary from 9 to 16 inches, "the average being 12 inches." The late Mr. Hemans, C.E., considered that "the mean will amount to 12 or 14 inches." Mr. Duncan, C.E. (Liverpool), found by actual measurement that the loss varied very little, though the difference of rainfall was considerable. He considered 11 or 12 inches was the "constant" loss (at Liverpool). Mr. Hawksley, C.E., has stated that "it amounts rarely to so little as 11 and 12 inches, and very commonly upon hilly ground to 13, 14, and 15 inches." "Evaporation," says Mr. Hawksley, "is more nearly 15 inches than any other quantity."

LVII.—Quantity or Proportion of Rainfall thrown off Pervious and Impervious Surfaces and available, if collected, for Storage.—The quantity of water in excess of that which is absorbed and evaporated from pervious (or porous) surfaces, and impervious (or non-porous) surfaces, and which runs off the surface into our rivers, and by our rivers to the sea, and is therefore available for storage on the surface, necessarily varies as much as any other condition affecting the water question.

Taking a general view of the matter, it may be stated that on the northern and western side of the country, including Wales, the amount of surface water at the disposal of man for storage, though it varies in different parts in a remarkable degree, cannot be less on an average than 20 inches, if we include in the estimate the highest and mountainous surface found in the wettest districts.

In the Midland, Southern, and Eastern Districts, the mean depth of water run off in the shape of floods and freshets, and in like manner available for storage, has been represented to be 6 inches, though, if the outflow of the Thames may be taken as a criterion, a less quantity would perhaps be more correct.

Some interesting information bearing on this point was given by Mr. J. Thornhill Harrison, before the Water Supply Commission in 1867, from which it appeared that the average annual dry weather outflow of the Thames was 6·86 inches. The period of observation extended over 11 years, from the 1st April, 1855, to the 31st March, 1866, during which time the mean annual fall of rain in the Thames basin was 27·74 inches, while the mean annual discharge of water by the river, measured at Kingston, was 9·25 inches, or 2·39 inches more than the average dry weather outflow just noted.

The minimum annual discharge of the Thames during the 11 years was that of the year ending the 31st March, 1859, when it was reduced to 5·49 inches, or 1·37 inches below the average dry weather outflow. The rainfall of the year 1857 had been 22·76 inches, and that of 1858 24·60 inches, with a remarkably dry winter intervening.

LVIII.—Waters Classified according to Source.—To exhibit the quality of water to be obtained from different sources there is no better classification than that by which the passage of water has already been traced from the condensation of atmospheric vapour into rain to its outflow from the earth.

In the sixth report of the Rivers Pollution Commissioners, which is a comprehensive exposition of the *chemical* view of the water question, the different waters obtainable in this country are treated in the following order:—(1) Rain water; (2) Upland surface waters from uncultivated, or but slightly cultivated, surfaces not manured; (3) Surface waters from cultivated lands; (4) Shallow well waters; (5) Deep well waters; and (6) Spring waters.

LIX.—Waters Classified according to the Results of Chemical Analysis.—In the "conclusions" arived at by the Rivers Pollution Commissioners, and set forth in the report referred to, the average composition of "unpolluted waters" is given in the following form:—

Results of Analysis expressed in parts per 100,000.

| Description. | Dissolved Matters. | | | | | | | | | | | No. of samples taken. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total solid impurities. | Organic carbon. | Organic nitrogen. | Ammonia. | Nitrogen as nitrites and nitrates. | Total combined nitrogen. | Previous sewage, or animal contamination. | Chloride. | Hardness. Temporary. | Hardness. Permanent. | Hardness. Total. | |
| CLASS I. Rain water ... | 2·95 | ·070 | ·015 | ·029 | ·003 | .042 | 42 | ·22 | ·4 | ·5 | ·3 | 39 |
| CLASS II. Upland Surface water ... ... | 9·67 | ·322 | ·032 | ·002 | ·009 | ·042 | 10 | 1·13 | 1·5 | 4·3 | 5·4 | 195 |
| CLASS III. Deep well water | 43·78 | ·061 | ·018 | ·012 | ·495 | .522 | 4,743 | 5·11 | 15·8 | 9·2 | 25·0 | 157 |
| CLASS IV. Spring water ... | 28·20 | ·056 | ·013 | ·001 | ·383 | ·396 | 3,559 | 2·49 | 11·0 | 7·5 | 18·5 | 198 |
| Average ... ... | — | ·127 | .019 | ·011 | ·222 | ·250 | — | 2·24 | — | — | — | — |

Without professing to appreciate thoroughly the expression "previous sewage or animal contamination," which is the heading to one of the columns, these figures are given because they may serve as "attainable standards" of pure water (from whatever source it may be derived), by leaving out, if desired, the speculative column just referred to.

The chemical examination so carefully given to the subject led the Commissioners to adopt the following division of waters in the order of quality :—

"Wholesome" waters were declared to consist of

1. Spring water.
2. Deep well water.
3. Upland surface water.

"Suspicious" waters to be

4. Stored rain water.
5. Surface water from cultivated land ; and the

"Dangerous" waters to be

6. River water to which sewage gains access.
7. Shallow well water."

Numbers 1 and 2 were stated to be "very palatable ;" 3 and 4 "moderately palatable ;" and 5, 6, and 7 "palatable." Preference is given to spring and deep well waters for purely domestic purposes over upland surface waters.

The conclusions come to by the Rivers Pollution Commissioners may be summed up in the following terms under their respective heads.

LX.—Wholesome Waters.—Of all the waters obtainable in this country those that receive the preference of the Commissioners are spring and deep well waters. Such waters, they say, are of inestimable value to communities, and their conservation and utilization are worthy of the greatest efforts of those who have the public health under their charge. They say, also, that water collected from the surface of uncultivated lands, when filtered through sand, constitutes upland surface water of good quality for domestic use, and of still better quality for manufacturing purposes. It is nearly always wholesome, but sometimes suffers in palatability from containing an excessive quantity of peaty matter in solution.

*Spring Water.*—Wherever springs bursting naturally from the out-crops of impervious strata in high grounds, or rising by pressure in valleys—which the Commissioners consider equal or superior in quality to the waters of deep wells—are available, the engineer should invariably turn them to account. Unluckily, however, springs of a superior potable quality, and of available quantity, exist only in exceptional places. They are extremely variable in

character, and cannot therefore be considered as a source of supply which can be generally or even frequently adopted.

*Deep Well Water.*—No engineer will deny, as a general proposition, that water which has passed through natural soil, unaffected by any mineral impurity, to deep subterranean levels in the water-bearing strata, is, where available for use, the most acceptable of all waters for drinking purposes. Any organic matter which it may have contained will have been perfectly oxidized and transformed into innocuous mineral compounds when passing through the aërated soil, but inasmuch as the obtaining of water from deep wells is attended with many disadvantages, besides that of the great cost incurred in sinking and pumping, the engineer cannot look forward to any very extended use of this source of supply for small villages, or for isolated dwellings.

*Upland Surface Water.*—In mountainous and hilly districts, where sufficient areas of impervious gathering grounds can be found, the best means of supply, because it is of a character over which the engineer has most command, is that which the Rivers Pollution Commissioners have placed third and last on the list of "wholesome waters." I refer to the storage of rain water thrown off uncultivated surfaces and collected before it becomes contaminated by foreign matters.

In the northern and north-western districts of England the rainfall of the higher grounds is at present collected and stored for the use of many of our manufacturing towns, and experience has proved the superiority of the supply. The sanitary engineer will find many examples in this country which he would do well to study. The waterworks for the supply of Glasgow and Greenock, in Scotland, and those of Manchester, Sheffield, Barnsley, and many other places in England, are admirable specimens of the kind of source to which this section refers. Profiting by this experience, it has been proposed to convey waters that may yet be collected and stored in these districts to the metropolis and other populous places, and this mode of water supply might also be turned to advantage in the case of isolated dwellings, but as the droughts of recent years have proved that scarcity may be felt even in the midst of abundant *average* rainfalls, this proposal has not gained favour, particularly since it has been advanced, with much force, that until the resources of each river basin have been exhausted, it would be opposed to national economy to appropriate the supply naturally belonging to other districts. It is held that the adoption of this proposal would prevent the future growth of those industrial communities which have located themselves in particular parts of the country in consequence of this very superabundance of water.

The conflict of opinion entertained on this question must have an important influence on the work of the engineer, and the words of the Royal Commission on Water Supply, that "no town or district should be allowed to appropriate a source of supply which naturally and geographically belongs to a town or district nearer to such source," will meet with general approval.

LXI.—Suspicious Waters.—Of these the Commissioners say that when rain from specially cleansed surfaces is collected at a distance from towns, and kept in clean receptacles, it "contains the smallest proportion of total solid impurity, but the organic contamination even of such specially collected water somewhat exceeds that of water from springs and deep wells." Rain water collected from the roofs of houses and stored in underground tanks they state to be much more impure, while the water collected from the surface of cultivated lands and from the under-drains of cultivated lands, is always more or less polluted with the organic matter of manure, even after subsidence in lakes or reservoirs. Such polluted surface or drainage water is, they declare, not of good quality for domestic purposes, but it may be used with less risk to health than polluted shallow well water, if human excrementitious matters do not form part of the manure applied to the land.

*Stored Rain Water*.—If, for the reasons already stated, we cannot obtain deep well water, or spring water, or water from upland (uncultivated) surfaces for those towns and villages and dwellings which are scattered over the rural portion of the country, we are necessarily obliged to have recourse to those waters which are pronounced by the Rivers Pollution Commissioners to be "suspicious," *i.e.*, water collected from roofs and impermeable (artificially made) surfaces, water to be obtained from cultivated lands, and the water from under-drainage. These waters they declare to be always more or less polluted with organic matter; but in the face of that judgment I am disposed to believe that the engineer must frequently look to such waters, when subjected to domestic filtration, as the means of supply wherever sewage contamination prevents the use of rivers or shallow wells, for there are localities in all countries where, in the absence of river and pure well water, rain water from roofs or prepared impermeable surfaces constitutes the only source of supply for separate dwellings. In providing potable water in such cases, it is the duty of the engineer to do his best to remove the objections of the chemist, and this he may do by the means to be taken—first, in collecting, next in storing, and lastly in filtering the water which he has collected and stored.

In fact, I hold the opinion that there exists no more certain

source of a pure and sufficient supply than that of properly collected and properly filtered rain water which is with care to be secured by all persons alike. There is no cleaner surface from which to collect rain than that of roofs formed of slates and the harder description of tiles, if pains are taken to prevent the growth of vegetation, the collection of decaying leaves, and the deposit of the excrements of birds, and proper means be taken afterwards to filter the water within the dwellings itself.

*The Waters of Under-Drainage.*—In some districts wide areas of wet land have been under-drained; and as winters succeed each other, a supply of water, varying from 30,000 to 70,000 gallons per acre, is annually discharged. Of this water the Rivers Pollution Commissioners go so far as to say, after the qualified condemnation I have quoted, that "the supply of such water can be very easily and safely accomplished wherever the subsoil drainage of pasture and meadow land is capable of collection in storage reservoirs of the moderate capacity sufficient for the needs of a mansion, hamlet, or small village." "The drainage from manured arable land is, as we have stated, by no means a desirable source of potable water, and must be unreservedly condemned if human excrements are used as manure. But with that exception the drainage water of even arable land is preferable to that from polluted shallow wells which are at present the usual source of the water supply in country places."

By the water of under-drainage (as I use the term) is meant the water extracted from the subsoil by under-drains laid in it at depths varying from three to six feet or more. This water forms a new source of available supply, because the rain which fell upon retentive or saturated soils, before they were under-drained, was either absorbed and held by them to be evaporated and lost as vapour in the air, or it was thrown off the surface and lost as water in times of flood or excess.

The same lands when drained absorb the rain, instead of allowing it to be evaporated or thrown off the surface. It infiltrates to the level of the under-drains, and passes out of the subsoil gradually by the drains to the outfalls, leaving behind in the soil only just enough water to satisfy its naturally retentive properties. Comparing this water, which has had the benefit of filtering through four feet or so of earth, with that which is now generally used in rural districts, and which is often obtained off roads and land surfaces when river and well waters fail, and are known to be decidedly deleterious, it is impossible to deny that the substitution of one for the other would be a very great advantage.

In many cases the water discharged from the under-drains of land may be collected and "refiltered" through natural soil

without any great increase of expense and with every probability of completely oxidising and rendering harmless any organic matter that may remain in it.

*Waters collected from Cultivated Surfaces.*—This last expedient (filtration through natural soil), may also be applied beneficially to waters collected from the surface of cultivated lands where human excrements are not used as manure. When investigated by the engineer it will often be found that the water of streams running through private estates, and made up of surface waters from cultivated lands, may be diverted out of their courses on to the surface of small areas of land near at hand, which, if purposely prepared by proper under-drainage, will absorb and discharge such water after freeing it from those impurities which it gathers as it passes over the contributing surfaces.

LXII.—DANGEROUS WATERS.—In this class the Commissioners prominently place rivers and streams to which sewage gains access. They say: (1) that when the sewage of towns or other polluting organic matter is discharged into running water it is not possible to render that water fit for drinking; (2) that the admixture of a small quantity of the specific poisons capable of producing cholera and typhoid fever with a large volume of drinking water is sufficient for the propagation of those diseases; (3) that "there is no river in the United Kingdom long enough to secure the oxidation and destruction of any sewage which may be discharged into it even at its source;" (4) that artificial filtration constitutes no effective safeguard against the propagation of those epidemics by polluted water; and (5) with respect to "shallow well water," they state that whenever the wells are situated—as is usually the case—near privies, drains, and cesspools, it is more dangerous than river water.

*River Water.*—The Commissioners therefore recommend the abandonment of rivers generally as a source of water supply, wherever the liquid refuse of human habitation is admitted into them, and they unhesitatingly state that both the River Thames and the River Lee should be abandoned as a source of water supply for domestic use. In speaking of the Thames, they say, that "there is no hope of this disgusting state of the river being so far remedied as to prevent the admixture of animal and other offensive matters with the filtered Thames water as delivered in the metropolis." They therefore recommend that "the Thames should, as early as possible, be abandoned as a source of water for domestic use." In speaking of the Lee, they say, "the water of the Lee is slowly, though irregularly, deteriorating from year to year, and there is no hope of purifying it to such an extent as to

render it at all times safe for domestic use." Consequently they "recommend that the Lee should be also abandoned as a source of potable water."

*Shallow Well Water.*—As to the waters of shallow wells the Commissioners, having examined many samples from wells in different geological formations, declare them to be, with very few exceptions, "entirely unfit for human consumption." In speaking, however, of those in the new red sandstone, they say that owing to the highly oxidizing power of the soil of this formation, the proportion of organic matter is generally more moderate than that met with in unpolluted surface waters. It is therefore needless to refer any further to this source of supply.

LXIII.—Quantity required for Consumption and Use.—The quantity of liquid which is drunk by human beings necessarily varies with the age and occupation of the consumer. The average quantity drunk by both sexes of all ages and of different occupations is really very small, when compared with the quantity we are accustomed to consider is required by the population of this country. It does not reach three pints per head a day, and this covers every description of liquid consumed. It savours of the ridiculous to speak of water-famine when the total quantity of liquid (of every description) drunk by each person does not, in fact, exceed in amount the quantity of water that would fall as rain in twelve months upon a good-sized umbrella if exposed for the purpose in either of the counties of Devon or Cornwall. From the *Report on the Army and Navy Diet Scales* I find that the estimated quantity of liquid of all kinds drunk in the two services averages 187½ gallons per head per annum, or about two quarts per day. Though this quantity is drunk by adults of the male sex it is some criterion of the quantity drunk by men, women, and children, and it will not be wrong to assume that two-thirds, or 125 gallons per head, is as much as is actually consumed by a mixed population in a year. Dr. Parkes says that an *adult* requires daily from 70 to 100 ounces (3½ to 5 pints) for nutrition, but about 20 to 30 ounces of this quantity are sometimes in the solid food.*

The water we drink, however, is, as we all know, not the only water that affects human health. All water mixed with solid food and used for cooking, and, I would add, the water used for personal ablution, and for the washing of the clothes we wear, and the utensils used in cooking, have a material though not so direct

* The living animal is made up for the most part of water. A "model" man of 154 lbs. contains 116 lbs. of water and only 38 lbs. of dry matter.—*Johnston.*

an influence on our sanitary condition. The quantity used in these different ways, when added to that which is drunk in one shape or another by the various descriptions of persons and communities of which all populations consist, does not together reach eight gallons per head, and in rural districts will not amount to half that quantity.

Eight gallons may be safely taken as representing the extreme quantity of water required, of which the quality must be of the purest.

The additional supply required for every household purpose, if the rules of cleanliness are duly observed,—including the water used in closets, and in washing floors, &c., as well as that used in stables, in the washing of carriages, and for other outside purposes, increases the 8 gallons to 15 gallons per head. All beyond this quantity taken for private use is mere waste, which would cease to exist if, in addition to a fixed charge for that quantity, every consumer paid for what he had besides.

It will have been understood that this quantity of 15 gallons per head is exclusive of the water used in trade, and of that devoted to public purposes, which, taking the mean quantity used in ordinary towns—I do not refer to towns in which special trades prevail—will be found to amount to 10 gallons per head, thus raising the total consumption to 25 gallons per head. I have found on investigating the quantity of water used in different trades that as much as two millions of gallons per diem have been used in one business alone. It is difficult to strike an average, when such extremes as this are included, for such a quantity would, in truth, serve a town with a population of 80,000, consuming 25 gallons per head.

Disregarding such extraordinary uses, I believe that we may take 25 gallons per head per diem as an ample supply for the generality of towns, while 15 gallons will suffice for rural villages; the supply of more than these quantities of water only results in waste.

LXIV.—Hard and Soft Water.—It is always important that the inhabitants of dwellings should be acquainted with the hardness or softness of the water supplied to them for their use. In ordinary acceptance the terms "hard" and "soft" refer to the comparative soap-destroying power of water, which depends upon the saline matters contained in it—the principal being chalk, gypsum, and common salt. When these substances are present in full quantities the water is rendered very "hard." There are two kinds of hardness, temporary and permanent hardness, requiring consideration, which are thus described by Dr. Meymott Tidy in his work *Handbook of Modern Chemistry*—"(*a*) *Temporary hardness is hardness due to calcic or magnesic carbonates.*

These salts are almost insoluble in pure water, but are freely soluble in water containing carbonic acid. On boiling the carbonic acid is expelled, and the carbonates are precipitated, hence temporary hardness is that hardness which may be got rid of by boiling the water. (*b*) *Permanent hardness, i.e., hardness due to calcic and magnesic sulphates, &c.* This is not got rid of by boiling. By the term "total" or "initial hardness" is implied both the temporary and permanent hardness of a water.

When expressing the hardness of water in degrees per gallon, it is always understood that each degree represents one grain of bicarbonate or sulphate of lime in the gallon.

The purposes for which water is used being so widely different and numerous, it is a difficult thing to speak decidedly as to the point at which water may be said to become hard. If water be solely reserved for drinking purposes, it may be hard without any evil consequences resulting from its use, and even be called soft, while if the same water be used for washing purposes, it would be termed very hard, and a great waste of soap, labour, and time would be caused. For cooking purposes a hard water is most disadvantageous, vegetables lose their flavour, and the strength of tea and soups is scarcely half extracted, while for personal ablution we all know from experience that soft water is much more pleasant than hard. It should also be stated that in chalk districts there is generally a considerable deposit of fur in the inside of boilers, pipes, &c., which may in time obstruct the passage of heat, and be the cause of accidents.

An able authority has thus classified water supplied for the general purposes of a dwelling: 1st class, not containing more than 5 degrees of hardness per gallon; 2nd class, containing from 5 to 10 degrees; and 3rd class, containing from 10 to 20 degrees —(*R. S. Burn*).

The Rivers Pollution Commissioners put the several waters derived from various sources in the following order, having regard to their hardness:

1. Rain water (softest).
2. Upland surface water.
3. Surface water from cultivated land.
4. Polluted river water.
5. Spring water.
6. Deep well water.
7. Shallow well water (hardest).

They consider water at or below six degrees of hardness to be soft, and above that number of degrees to be hard.

Analytical chemists having improved on the invention of the late Dr. Clark, of Aberdeen, will now readily find out the degree of hardness of any water that may be sent to them for the purpose, by ascertaining how many measures of a standard solution of soap

are required by a stated quantity of the water in order to form a lather.

As is well known, Dr. Clark, nearly 30 years ago, invented a process of water softening which, having stood the test of all that time, is as much approved of at the present moment as it was then. It is thus most concisely described in Mr. Burn's work on Sanitary Science. "To understand the nature of the process it will be necessary to advert in a general way to a few known chemical properties of the familiar substance chalk; for chalk at once forms the bulk of the chemical impurity that the process will separate from water, and is the material whence the ingredient for effecting the separation will be obtained. In water chalk is almost or altogether insoluble, but it may be rendered soluble by either of the two processes of an opposite kind. When burned as in a kiln chalk loses weight, and if dry and pure only nine ounces will remain out of a pound of sixteen ounces. These nine ounces will be soluble in water, but they will require not less than forty gallons of water for entire solution. Burnt chalk is called quicklime, and water holding quicklime in solution is called lime water. The solution thus named is perfectly clear and colourless. The seven ounces lost by a pound of chalk on being burned, consist of carbonic acid gas, that gas which being dissolved under compression by water forms what is called soda water. The other mode of rendering chalk soluble in water is nearly the reverse. In the former mode a pound of chalk becomes dissolved in water in consequence of losing seven ounces of carbonic acid. To dissolve in the second mode not only must the pound of chalk not lose the seven ounces of carbonic acid that it contains, but it must combine with seven additional ounces of that acid. In such a state of combination chalk exists in the waters of London, dissolved, invisible, colouress, like salt in water. A pound of chalk dissolved in five hundred gallons of water by seven ounces of carbonic acid would form a solution not sensibly different in ordinary use from the filtered water of the Thames in the average state of that water. Chalk which chemists call carbonate of lime becomes what they call bicarbonate of lime when it is dissolved in water by carbonic acid. Any lime water may be mixed with another, and any solution of bicarbonate of lime, without any change being produced. The clearness of the mixed solutions would be undisturbed. Not so, however, if lime water be mixed with a solution of bicarbonate of lime. Very soon a haziness appears. This deepens into a whiteness, and the mixture soon acquires the appearance of a well mixed whitewash. When the white matter ceases to be produced, it subsides, and in process of time leaves the water above perfectly clear. The subsided matter is nothing but chalk."

"This is the basis of the process. Hard water contains chalk

in the form of bicarbonate of lime. By the addition of lime water the chalk is precipitated, and the water left above is clear, colourless, and soft, not holding in any sensible degree either a solution of quicklime or bicarbonate of lime."

"Wherever the plan has been adopted it has been successful."

Such is the well known "Clark's process." Its application, however, has been generally limited to large public examples owing to the time (24 hours) requisite to allow the precipitate to fall to the bottom after the mixing has been effected, and before use. This delay must necessitate the storage in tanks of several days' supply, which, in the case of large dwellings and institutions, where a great quantity of water is consumed, is very objectionable.

Among many suggestions to avoid this delay, one means invented by Messrs. Atkins, that of passing the water through a filter, so as to filter out the precipitate, instead of *waiting* for it to fall to the bottom of its own gravity, has been adopted, and may facilitate the more general use of Clark's process.

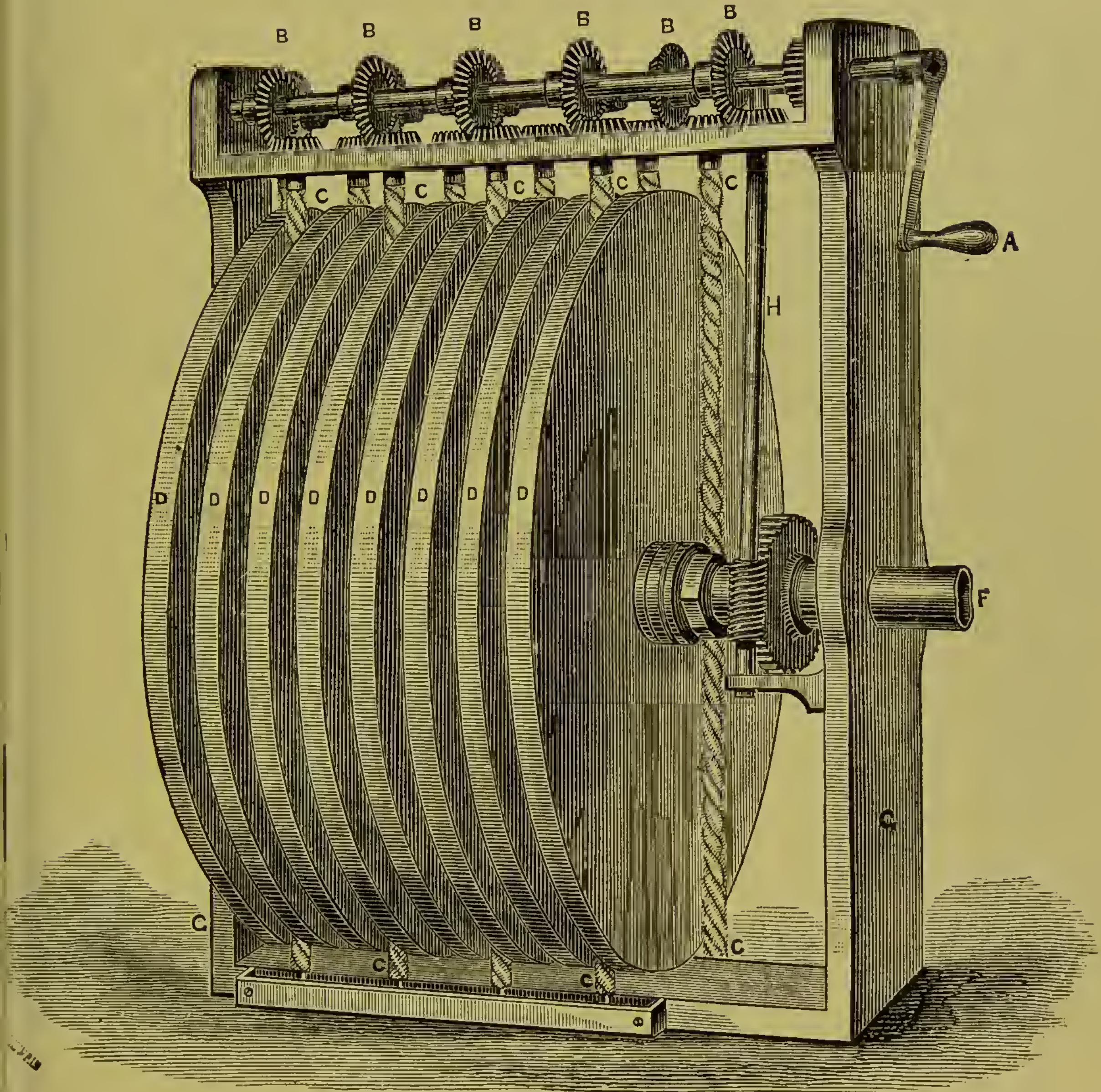
In small houses, however, a rough and ready way out of the difficulty may be sometimes advantageously adopted. It consists of three ordinarily sized cisterns. One is placed above the other two, and is the receptacle for the preparation of lime water. The lower two contain the water supply of the house, and are brought into use on alternate days, being in turn supplied with the lime water from the upper cistern. The draw off taps from the two lower cisterns should always be placed at a height of some few inches above the bottom to allow for sediment, and there should also be a line mark on the outside of each to show the height to which the lime water from the upper cistern should be added before the hard water from the main is admitted. This method does not require more than a small amount of daily attention, and the cisterns should not occupy much space.

Messrs. Atkins thus describe their own invention.

"The filter consists in the first place of a number of discs of perforated metal with filter cloth stretched over them, so arranged as to present the largest amount of filtering surface in the smallest compass. These discs are hollow and are fitted into a central tube, which forms the main channel for carrying off the filtered water."

Fig. 79 (next page) represents the filter apart from the tank or high pressure case in which it is subsequently fitted. The discs are shown at D, and the filtered water is carried off by the outlet F.

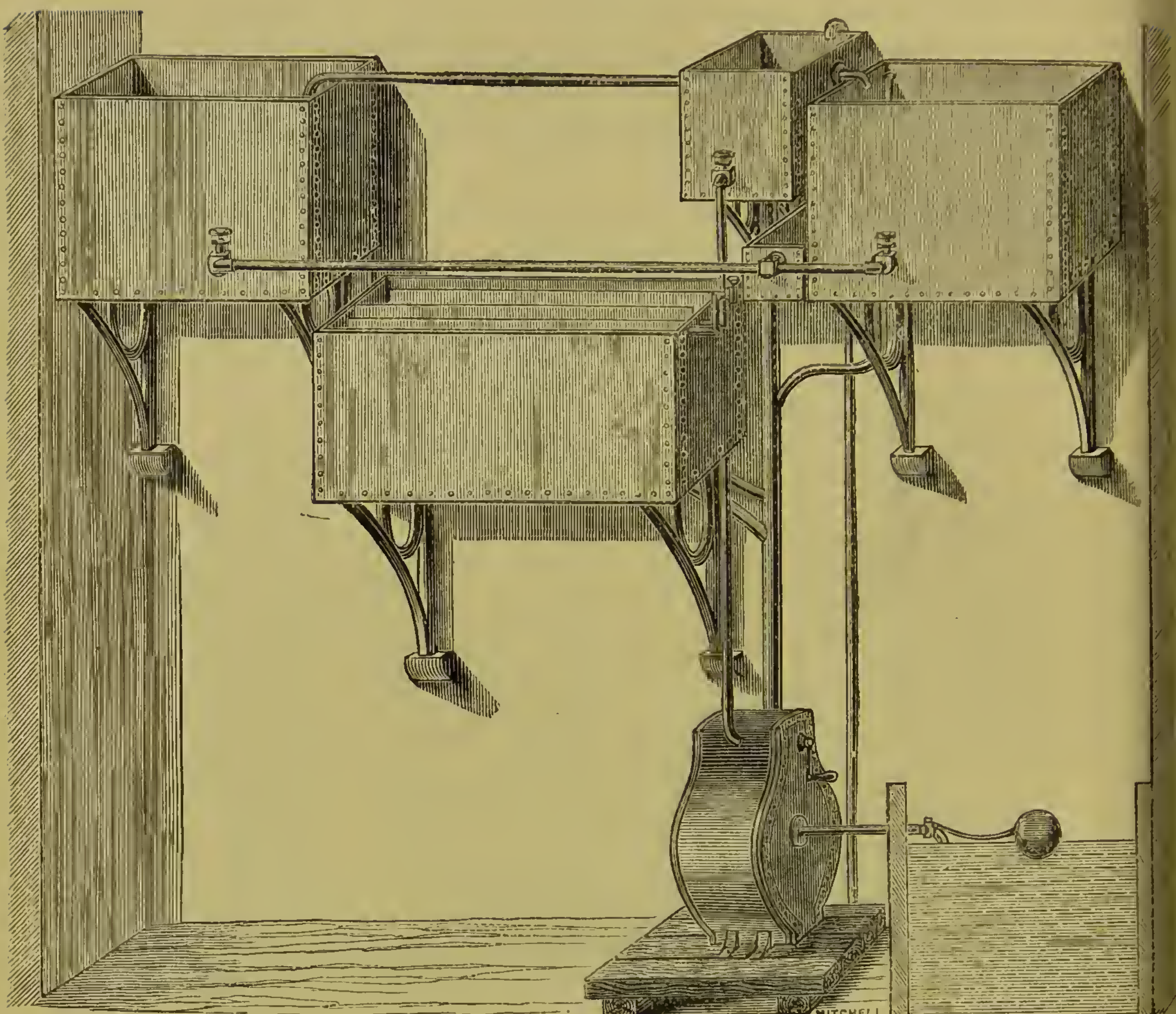
Fig. 79.




To clean the surfaces of these discs the handle A must be turned. This turns the cog wheels B which set the brushes C rapidly revolving, each on its own axis, against the surfaces of the discs. The handle A also communicates motion to the discs themselves, through the rod H, wh'ch by means of a worm causes the discs to revolve slowly, and brings every portion of their surfaces by degrees in contact with the rapidly revolving brushes. Thus in a very few seconds the discs have been brushed clean, and after a short delay to wash out the collected sediment, the machine is ready for use again.

Fig. 80 shows the complete water softening apparatus, and illustrates how it may be fitted up in a country mansion.

Fig. 80.




The apparatus complete includes the following—

(1.) A tank to store the mixture of lime water.

(2.) Two tanks, one containing a reserve of water to be treated, and the other a graduated amount of the lime water to be mixed with it.

(3.) The mixing chamber where the two streams meet and become thoroughly intermixed.

(4.) The filter to receive the water as it flows from the tanks above, and to deliver it to the ordinary house cistern shown at the bottom of the drawing.

Another process largely in use for the softening of water in public institutions and large mansions, where a large supply of

water is consumed is the Porter-Clark process, which in principle is very similar to Atkins' method just described. It is, however, subject to the same drawback, of being hardly suitable, owing to the large expense entailed by it, for ordinarily sized dwellings.

LXV.—On Water Analysis.—It is to be regretted that there exists no capability on the part of householders of testing the degree of purity characterising the water they have to drink. It is not to be desired on scientific grounds that the uninitiated should experimentalize on so vital a question, but it would nevertheless be a great boon if every one possessed of common sense could at least be able to ascertain whether the water he is drinking is of a suspicious character or not.

But so long as different chemists adopt different proportions and forms of analysis—some giving in their reports grains and decimal parts of a grain in a gallon of 70,000 grains, others parts and decimals in 100,000 parts, while others, again, give parts and decimals in 1,000,000 parts, it is very improbable that facility will be afforded to enable householders to ascertain for themselves whether they may continue to drink the water supplied to them with safety. Some of the most eminent chemists of the day adopt the terms "organic carbon" and "organic nitrogen" when demonstrating the amount of pollution, whilst others adopt "albumenoid and free ammonia" to express the same object. From these facts we may conclude that the amount of ignorance which now prevails, and which we are told should be removed, is likely to remain so long as our professors adopt different languages to express the same thing.*

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* As an example it may be stated that Professor Frankland gives the analysis of water supplied by the Lambeth Company to the metropolis in the following terms :—

Results of analysis in parts per 100,000—

| | |
|---|---|
| Temperature in centigrade degrees ... ... ... | 14·00 |
| Total solid impurity ... ... ... ... ... | 27·52 |
| Organic carbon ... ... ... ... ... ... | ·149 |
| Organic nitrogen ... ... ... ... ... | ·038 |
| Ammonia... ... .. ... ... ... ... | nil. |
| Nitrogen as nitrates and nitrites ... ... ... | ·193 |
| Total combined nitrogen ... ... ... ... | ·231 |
| Previous sewage or animal contamination ... ... | 1610° |
| Chlorine ... ... ... ... ... ... ... | 1·95 |
| Total hardness ... ... ... ... ... ... | 20·9 |

Whilst Professor Attfield thus analyzes water from the same source, "One

The nearest approach to a test adaptable to the general public is that of permanganate of potash in some form or another,* though the safest thing to do, under present circumstances, when the quality of water is at all doubted, is to send a sample to a competent analytical chemist. Not less than two gallons should be sent in glass bottles with glass stoppers, and care must be taken not only that the bottles are perfectly clean, but that they have been well washed out—at least twice—with the water that is to be analysed, before the final sample is sent off. The stoppers should be sealed down and the date and other attendant circumstances legibly noted on the outside of the bottles.

---

gallon," he says, "contains the following number of grains and decimal parts of a grain of the respective substances :—

| | |
|---|---|
| Total solid matter dried at 212° F. ... | 14· |
| Ammoniacal matter yielding 10 per cent. of nitrogen, equal to ammonia per million 0·01 ... ... ... ... ... | ·006 |
| Albumenoid organic matter yielding 10 per cent. of nitrogen, equal to ammonia per million 0·04... ... ... ... | ·024 |
| Nitrites ... ... ... ... ... | none. |
| Nitrates, containing 17 per cent. of nitrogen (equal to grains of nitrogen per gallon 0·025) ... ... ... ... ... | ·15 |
| Chlorides, containing 60 per cent. of chlorine (equal to grains of chlorine per gallon 1·3) | 2·2 |
| Hardness, reckoned as chalk grains or degrees ... ... ... ... ... Removed by ebullition, 8·0 ... ... Unaffected by ebullition, 2·5 ... ... | 10·5 |
| Lead or copper ... ... ... ... | none." |

* Tests for Decomposed Organic Matter.—Permanganate of potash, as it is most generally obtained, is a salt dissolved in very pure water. It is remarkable for its colouring power, and communicates a bright violet rose colour when first added to the water to be analysed. If decomposed organic matter be present in a degree hurtful to health, this colour is changed to a dull yellow ; or if a still larger quantity exist in the water, the colour will in time entirely disappear. Where the colour is rendered paler, but still retains a decided reddish tinge, then we may infer, that although putrefying organic matter is present, it is so in such minute quantities as are not likely to be immediately hurtful. One drop to a small quantity of water, or two to a larger quantity, is the quantity of this fluid to be added. It should be allowed to stand for two hours ; if, however, the change in colour takes place before the expiration of this time, it is a strong indication of the impurity of the water—the rule being that the quicker and more perfect the discolouring of the water tested, the greater is the quantity of decomposing organic matter present : if also, upon the addition of a few more drops, a change in colour is manifested, it is a sign that a very large and dangerous quantity of putrefying organic matter is present. Another simple test for organic matter is that of dissolving in water a small quantity of white sugar. In a few days if any organic impurity is present, the water will become white and milky. This test is, however, not so reliable as that of permanganate.

## CONTENTS OF CHAPTER VIII.

### SOURCES OF SUPPLY.



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## CHAPTER VIII.

LXVI.—ADVANTAGES OF PUBLIC OVER PRIVATE SUPPLY.—In all districts where the supply of water is obtained from a source in the hands of a sanitary authority or a public company, the occupants of dwellings will generally do well to accept that supply, instead of looking for one of their own, for the instances are rare in which a better or safer one can be obtained from private sources. Moreover, if the actual cost of water obtained by means of a general supply be compared with that derived from private sources, it will be found that, in the majority of cases, the former will be the cheaper of the two. Where a general or combined supply is adopted in rural parishes or districts, the population of which is sparse and comparatively poor, it it just possible that the annual charge on private dwellings, which, on an average, reaches 1*s.* only, may reach 1*s.* 6*d.* in the pound on their rateable value. A dwelling of which the rateable value is £100 a year, would then be charged as much as £7 10*s.* per annum, or nearly 5*d.* per day, which is high, though not so high as to deter householders from taking it at the price; but supposing the quantity of water consumed daily in such a dwelling to be 300 gallons, the charge would then reach a penny per 60 gallons delivered to the premises. It is impossible to deny that though this rate of charge very much exceeds that of large towns, it would be very much less than a resident of such a dwelling in the country expends in pumping, or otherwise providing the same quantity of water for the use of his establishment.

These remarks, which favour combined supplies in rural as well as urban districts, do not, of course, apply to dwellings held with lands of an extent and character sufficiently large to furnish water from springs or from uncultivated surfaces, and to allow of its delivery

by gravitation. They refer to those very numerous instances where no general supply exists, and where individuals are dependent on wells or rivers, or upon surface waters to be collected and stored in tanks.

LXVII.—Wells of Various Kinds.—Up to this time, in nine out of ten cases where no general supply exists, the occupants of dwellings, as already shown, are dependent upon wells of different depths. These are generally called either "Deep Wells" or "Shallow Wells."

"Deep Wells" are technically understood to mean wells of any depth, which reach a subterranean bed in one of the water-bearing strata, and which, being fed by wide and distant contribution, never altogether fail in supply. In the majority of cases the power required to raise the water of such wells is greater than that of hand.

"Shallow Wells" are those which are fed by land or surface springs from sources of limited extent which may fail in very dry weather, and the waters of which are frequently raised by hand by a suction or atmospheric pump.

Between these two characteristic kinds of wells there are others which penetrate a greater depth than "shallow wells" without reaching a water-bearing stratum. The waters of these wells are raised by lift and force or centrifugal pumps, or by windlass and bucket. They are sometimes called deep wells, because the common suction pump is insufficient of itself to raise the water, though they more frequently than either "deep" or "shallow" wells fail in supply. They are as liable to defilement as the latter, while they are not benefited by the dilution due to the large body of water forming the supply of wells sunk into the water-bearing strata.

In the harder portions of the chalk and the new red sandstone, as well as in the oolites and older limestones, wells require simply sinking and forming without lining, but in clays and marls, in free and broken strata, and when passing through thin partings between rocks, they must be steined.

The character of the steining, and the method of executing it, will depend upon the depth of the wells and the precise nature of the strata through which they are sunk. In some cases the lining will consist of bricks, laid flat, without either cement or mortar. In others it will consist partly of courses of bricks laid dry and partly of courses laid in cement, the distance between the cemented rings varying from 5 to 12 feet according to circumstances. Under conditions of special difficulty the bricks should be laid wholly in cement. In cases where quicksands are met with, or where it is intended to shut out top water, iron cylinders are resorted to as the lining. The exclusion of surface waters is

sometimes effected by laying the brick steining in cement, and concreting or puddling between the bricks and the soil, and this may be quite sufficient in the majority of cases; but if the water which it is intended to exclude is of a polluting character—and the influx of a small quantity may be very prejudicial—it should be borne in mind that there will always remain the possibility of its percolating through the soil outside the concrete or puddling, and rising up from the bottom to the level of the water in the well. In fact it is only where there are layers of impervious rock or clay, down to which the puddle or concrete can descend, and with which a perfect junction may be effected, that outer waters can be excluded from wells with certainty. With increasing experience concrete will find greater favour with well sinkers. For the steining of ordinary wells of small diameter, $4\frac{1}{2}$-inch work, with the bricks meeting end to end, is amply sufficient. Nine-inch work, with or without cement, is more appropriate when the ground is treacherous and the diameter of the well greater. In all cases radiated bricks should be used, and now that this form of brick is made with facility there is no reason why they should not be generally adopted.

The old method of executing steining by building on curbs of wood shod with iron, and allowing both curb and superstructure to sink down together, is not often now resorted to.

In considering, even cursorily, the construction of wells, the value of horizontal wells or adits—sometimes called galleries—as a means of storage, cannot be omitted. In certain formations, where a large quantity of water has to be raised from a single well in a given time, they are invaluable. At the well at Reid's Brewery, in the Clerkenwell Road, in which galleries were driven in the chalk at a depth of 200 feet from the surface, and 64 feet into the chalk, the yield is stated to be 192 gallons per minute, or 101,178,000 gallons per annum. Water rises in the well to a height of 121 feet from the surface. The height of the surface is 70 feet above sea level, and the water therefore stands at 51 feet below the same datum. At Bishop Stortford, in a well of which the galleries were formed 154 feet below the surface and 38 feet deep in the chalk, the yield has been 10,000 gallons a minute, or 5,256,000,000 gallons annually. Only 25 gallons a minute came from the shaft itself, the remainder being supplied by the galleries.

*Deep Wells.*—In the case of large establishments and public institutions, it will be necessary to have at command a supply of water, if it can be possibly secured, which will not be readily affected by diminished rainfall; and the instances are few in which either the new red sandstone or the chalk will fail, unless the subterranean beds are being drawn upon at the same time by large communities.

The opinion of the Rivers Pollution Commissioners is here

given on the waters to be derived from these strata, which possess larger water-bearing capabilities than all the other formations of the crust of this country put together. They say that "Unpolluted waters drawn from deep wells in the *new red sandstone* are almost invariably clear, sparkling, and palatable, and are among the best and most wholesome waters for domestic supply in Great Britain. They contain, as a rule, but a moderate amount of saline impurity, and either none, or but the merest traces, of organic impurity. The hardness is usually moderate, and only when the water is derived from originally impure sources does it become excessive. There is every reason to believe that a vast quantity of hitherto unutilized water of most excellent quality is to be had at moderate expense from this very extensive geological formation." * * * * "The unpolluted deep well waters from the *chalk* rank amongst the best and most wholesome with which we have become acquainted. They are almost invariably colourless, palatable, and brilliantly clear. The chalk constitutes magnificent underground reservoirs, in which vast volumes of water are not only rendered and kept pure, but stored and preserved at a uniform temperature of about 10° C. (50° F.), so as to be cool and refreshing in summer, and far removed from the freezing point in winter. It would probably be impossible to devise, even regardless of expense, any artificial arrangement for the storage of water that could secure more favourable conditions than those naturally and gratuitously afforded by the chalk, and there is reason to believe that the more this stratum is drawn upon for its abundant and excellent water the better will its qualities as a storage medium become. Every 1,000,000 gallons of water abstracted from the chalk carries with it in solution, on an average, one-and-a-quarter tons of the chalk through which it has percolated, and thus makes room for an additional volume of about 110 gallons of water. The porosity or sponginess of the chalk must therefore go on augmenting, and the yield from wells judiciously sunk ought within certain limits to increase with their age. The only drawback to these waters is their hardness, but this disadvantage is greatly reduced by the circumstance that it is chiefly of the 'temporary' kind, and can be therefore easily and cheaply removed by the application of Clark's, or some other approved process."

These tempting words of the Rivers Pollution Commissioners must be received with considerable allowance, for it must not be forgotten that both the water in the chalk below London, and that in the new red sandstone below Liverpool, have sunk permanently 50 feet.

The well-sinker, moreover, does not always meet with a sufficient supply even in these strata. In the chalk he will occasionally fail altogether in reaching any supply, while in several instances the draught of certain wells has been known,

as previously shown, to seriously detract from the supply of others.

When sinking the trial-shaft at St. Margaret's Bay, to ascertain the condition of the earth through which the proposed Channel Tunnel would pass, Mr. Tilley, of Walbrook, bored through the chalk and green sand formations into the gault *without finding any water.* In the new red sandstone there has been experienced, in addition to occasional failures of supply, the disadvantage arising from the existence of gypsum, which gives an excessive degree of hardness to the water, while in some of the beds of the same formation salt prevails to such an extent as to render the water altogether unfit for domestic purposes.

As an engineer seeking water from subterranean sources must have reference to the geological features and the special circumstances of each particular case, some executed works, the particulars of which may be found useful, may be very briefly referred to.

In the new red sandstone, Messrs. Mather and Platt, of the Salford Iron Works, have done much in gaining water with their patent rock-boring machinery. The yields afforded by some of these borings are set forth in the following table :—

| Locality. | Diameter of bore. | Depth bored. | Supply of Water per day of 24 hours. |
|---|---|---|---|
| | inches. | feet. | gallons. |
| Hulme, Manchester ... ... ... | 13 | 259 | 86,400 |
| Stockport ,, ... ... ... | 12 | 348 | 50,000 |
| ,, ,, ... ... ... | 12 | 228 | 43,200 |
| Cheadle ,, ... ... ... | 12 | 145 | 55,200 |
| Patricroft ,, ... ... ... | 12 | 292 | 100,800 |
| Macclesfield ... .. ... ... ... | 12 | 94 | 66,240 |
| Stockport, Manchester ... ... ... | 12 | 182 | 34,560 |
| ,, ,, ... ... ... | 12 | 192 | 24,960 |
| Hulme, ,, ... ... ... | 12 | 189 | 46,080 |
| Warrington ... ... ... ... ... | 9 | 348 | 63,360 |
| Winwick, Warrington ... ... ... | 18 | 212 | 461,000 |
| Manchester . ... ... ... ... | 18 | 454 | 648,000 |
| ,, ... ... ... ... | 15 | 466 | 570,000 |
| Stockport, Manchester ... ... ... | 18 | 424 | 806,400 |
| Cardiff, South Wales ... ... ... | 18 | 248 | 720,000 |
| Manchester ... ... ... ... ... | 12 | 312 | 90,720 |

Mr. Tilley, who has had much experience in well sinking and boring in different formations, thus gives the results of some of his operations in the chalk and the new red sandstone. Speaking of the latter, he says that at Aston, near Birmingham, he sunk a well 100 feet deep and bored 300 feet for the Birmingham Water Company, and obtained a supply equal to 3,000 gallons a minute, or nearly 4,500,000 gallons daily. The bore-hole is 20 inches in diameter, and into it the suction pipe of the pump descends. The pump works a 10-ft. stroke at the rate of 9½ strokes per minute. In this instance Mr. Tilley says that the

water stands at a constant level, not varying a quarter of an inch even when the pumping is continuous.

The same well-sinker has executed sundry other works with different results. In 1861 he sunk, at a cost of £2,300, "No. 1 well," for the Wallasey Commissioners. It was 7 feet in diameter and 90 feet deep and was lined with cast iron cylinders. A boring was made at the bottom of the well partly 14 inches and partly 8 inches in diameter to a total depth from the surface of 250 feet: 24 hours pumping at the rate of 500 gallons per minute reduces the head of water 51 ft. 9 ins. In 1873 he sunk a similar well, known as "No. 2 well," about 20 feet distant from No. 1, and made an 18-inch bore-hole to a depth of 400 feet from the surface at a total cost of £2,677. The quantity raised from this well is 700 gallons a minute. Since the well was finished No. 1 yields a greater quantity of water than before, and the commissioners have enlarged and deepened it to the depth of No. 2.

Some valuable information in the form of the following table from Mr. Paton, of St. Albans, whose name is associated with the efforts made to supply London with water from the Colne Valley, and who has had very large experience in this kind of work, is here given :—

| —— | Depth. | | | Length of headings. | Size. | | | Daily yield in gallons. | Cost of sinking, boring, &c., including materials used. |
|---|---|---|---|---|---|---|---|---|---|
| | Sunk. | Bored. | Total. | | Sinking. | Boring. | Headings. | | |
| | ft. | ft. | ft. | ft. | ft. ins. | ins. | ft. ft. | | £ |
| Luton Waterworks ... | 50 | 272 | 322 | — | 6 0 | 10 | — | 200,000 | 405 |
| Edgware Public Well ... | 90 | 200 | 290 | — | 4 0 | 7 | — | 40,000 | 250 |
| Harrow Waterworks ... | 193 | 210 | 403 | — | 6 0 | 15 | — | 200,000 | 1940 |
| Henley-on-Thames ... | 246 | 234 | 480 | — | 5 6 | 6 | — | 40,000 | 480 |
| High Wycombe Waterworks ... | — | 171 | 171 | — | — | 10 | — | 120,000 | 238 |
| Temple Mills, Great Marlow... | 20 | 395 | 415 | — | 6 0 | 12 | — | 700,000 | 525 |
| Watford Brewery, Watford ... | 6 | 227 | 233 | — | 5 0 | 7 | — | 135,000 | 250 |
| Commercial Travellers' School, near Pinner ... | 32 | 110 | 142 | — | 4 6 | 6 | — | 60,000 | 150 |
| Hendon Union ... | 85 | 240 | 325 | — | 4 6 | 7 | — | 50,000 | 310 |
| Guildford Union ... | 210 | 124 | 334 | — | 5 0 | 6 | — | 40,000 | 327 |
| Berkhampstead Waterworks ... | 10 | 200 | 210 | — | 4 6 | 8 | — | 100,000 | 200 |
| Earl Brownlow's Estate, Ashridge ... | 255 | 90 | 345 | 320 | 6 0 | 10 | 7 × 6 | 288,000 | 2099 |

The last instance given in the foregoing table has a special bearing on the water supply of the dwelling, as it shows what a nobleman of wealth may do for the supply of his mansion, and for farms and villages near at hand. In this case, Mr. Paxton, the agent to the estate, says, that the water is raised by an

engine of 28 horse-power, working three-throw pumps, in sufficient volume to afford a constant supply to the mansion, gardens, and fountains, as well as to the villages and farms of Ringshall, Little Gaddesden, and Hudnall. The total cost of laying on the water—including well sinking and boring, engines, covered reservoirs, tanks and cisterns—was £11,018 18*s.* 2*d.*, while the average cost of repairs, attendance, and working expenses, amounts to £430 per annum.

Mr. Thomas Docwra, of Balls Pond, who has also had very wide experience in well sinking, says that he has found that many beds, both in the new red sandstone and in the chalk, differ very much in texture, as well as in their other characteristics. There are layers, he says, in the chalk quite as compact and solid as certain descriptions of rock: some beds, in fact, being used as a building stone. These are costly to get through. Comparing the soft with the hard portions, Mr. Docwra says the cost of excavation will be about half. With respect to the new red sandstone, he considers that, as a general rule, the cost may be taken to be about double that of the same work in the softer chalk, or about the same as the harder chalk. The cost of sinking wells—say of a diameter of seven feet—in the soft chalk is estimated by Mr. Docwra at 20*s.* per foot for the first 20 feet, to which must be added 5*s.* per foot for each 20 feet of additional depth; for instance:

| | | | |
|---|---|---|---|
| Wells from 20 to 40 | feet in depth, | 25*s.* | per foot. |
| do. 40 ,, 60 | ,, | 30*s.* | ,, |

With respect to boring, Mr. Docwra's figures are as follows:—

| | | | |
|---|---|---|---|
| 24-in. bore-hole, without piping, starting at 100 ft. from surface | 20*s.* per foot, increasing | 3*s.* per foot at every 20 feet. | |
| 18-in. ,, ,, | 16*s.* ,, | 2*s.* 6*d.* | ,, |
| 12 in. ,, ,, | 10*s.* ,, | 2*s.* 0*d.* | ,, |
| 6-in. ,, ,, | 8*s.* ,, | 1*s.* 6*d.* | ,, |

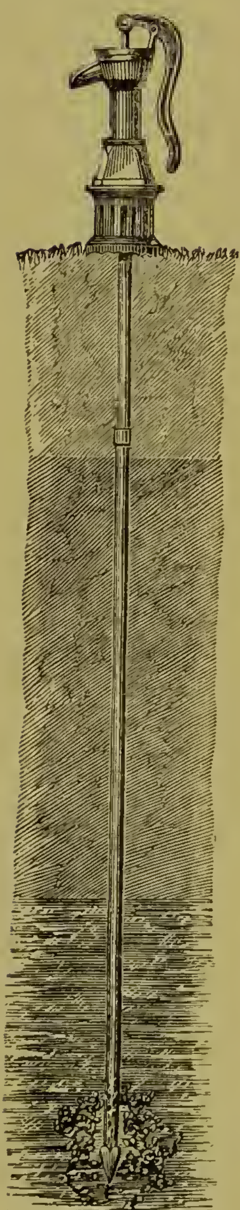
and he states that "the prices of cast and wrought iron pipes for lining bore-holes vary from 1*s.* per inch (diameter) per foot in the smaller sizes, to 1*s.* 6*d.* per inch per foot in the larger sizes. In driving headings in chalk the cost is governed by the depth from the surface; one at 100 feet, of the size of seven feet by four feet, would cost £2 to £3 per foot forward. These figures do not include any pumping that may be requisite during the carrying out of the work.

Mr. Tilley puts the cost of boring in the red sandstone and in the chalk as follows:—

| | Red Sandstone. | Chalk. | |
|---|---|---|---|
| 6-inch bore hole ... | 20/- ... | 20/- | Exclusive of pipes. |
| 12-inch ,, ... | 40/- ... | 32/- | |
| 18-inch ,, ... | 60/- ... | 54/- | |

Speaking generally, not only is the sinking of deep wells an expensive and, in some instances, a doubtful work in itself, but when the annual cost of pumping is added to the interest on the capital expended, the current cost often becomes a very formidable matter indeed. In large towns the expense of obtaining water from deep wells falls comparatively lightly upon the recipients, the number of inhabitants upon which it can be apportioned being large. It is found, too, in practice, that after great expense has been incurred in sinking deep wells, the labour of pumping, where neither steam, water, wind, or horse-power is resorted to, is so oppressive on servants, that the only water raised is that used for drinking and special purposes. Deep wells are then supplemented by shallow ("suspicious") ones, or by the storage of surface waters (also "suspicious"), so that the superior character of deep well water is partially lost, and the original outlay increased by the provision of two sources of supply.

FIG. 81.



*Shallow Wells.*—Of these wells as a means of supply to dwellings there is nothing further to say than that of 412 wells examined by the Rivers Pollution Commissioners with a view to ascertain their fitness for the purpose they served, there were very few yielding a supply of a sufficiently pure character to rank as "wholesome" water.

*Tube Wells.*—Although this condemnation of shallow wells is very general, it should be pointed out that wherever a constant supply of pure water can be found in a free soil within 20 or 25 feet of the surface, recourse may be very advantageously had to the Abyssinian (Norton's) tube wells (*see* Fig. 81). If these tube wells are adopted no shaft is sunk. The water is reached by driving or simply screwing the tube down through the ground to the water level. In localities where the water reached is below the range of a lift pump, it is necessary to employ tubes of a larger diameter than those adapted to shallow wells, and the plan by which the water is raised from any depth is described by Messrs. Legrand and Sutcliff, the makers of the Abyssinian well tube, in the following terms :—

"As soon as the first or pointed length has been driven, a working barrel, which consists of a short length of well tube lined with brass, is added to the well tube by placing the valve seat

D (*see* Fig. 83) into the working barrel (which is engraved in section in order to show the position of the lower valve seat and ring (*see* Fig. 82), and then screwing the working barrel on the well tube in the usual manner with the socket which has been taken off the well tube, until it fairly butts upon the well tube.

FIG. 82.

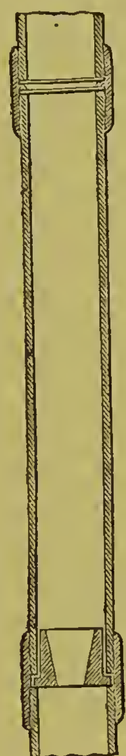


FIG. 83.

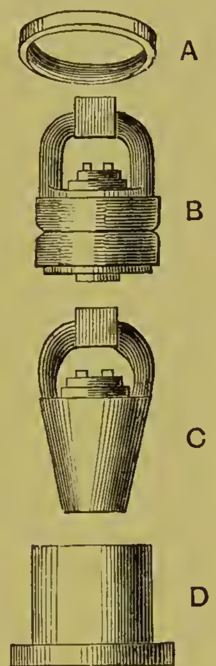
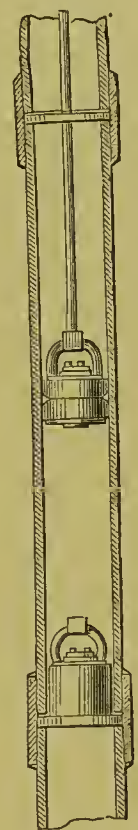



FIG. 84



"The ring A, with its broad part downwards, is next laid on top of the working barrel, as shown in Fig. 82, on to which the next length of tube is screwed in the ordinary way until it is firmly butted on to the working barrel, after which process driving is continued in the ordinary manner until water is reached, and when driven until there stands several feet of water in the tube, the lower valve C is lowered into its seating by means of a small hook provided for that purpose, which can be coupled to the pump rods.

"The lower valve having been carefully wound round with tow and a little tallow, is hung on to the hook above mentioned, and thus lowered down the tube until it reaches the valve seat D, as shown in Fig. 84; the hook is then disengaged from the valve and drawn up.

"The bucket B is next screwed on to one of the iron rods provided for the pump, and lowered down the tube well by adding as many of the rods as are necessary, until it reaches into

the working barrel, as shown in Fig. 84, and by allowing it to rap very slightly on to the lower valve C it will embed the lower valve firmly into its place.

"The rods that have been thus lowered have now to be coupled to the short length connected with the pump handle and passing through the barrel, the best way to do this being to remove the pump handle, when the short rod leading from it can be screwed into the coupling, and made secure like the rest of the joints by split pins. The pump head can then either be screwed or bolted on to the tube well, and when the handle is connected the whole is so far complete.

"To start the pump, water must be poured down through the top, and pumping commenced, and in a short time the water will commence to flow, the time varying according to the depth it has to be raised.

"At first it should be pumped rapidly, in order to get up as much of the grit and sand as possible, until it gets clear, and as soon as this is done the well is complete.

"In conclusion, it may be observed, that all remarks and instructions given for the smaller wells apply equally to the larger and deeper wells.

"A simple plan very frequently adopted with deep wells, where the depth at which the water stands is not very much below the reach of a lift pump, is as follows :—For instance, when a tube well has been driven, say 50 feet, and the water has risen only 12 feet, a hole, say 12 feet, can be dug, at which depth the ordinary pump can be attached, and the well cleared up, and then a working barrel can be coupled on with a larger tube reaching to the surface, and surmounted by a pump head as described. This large tube can be of either wrought or cast iron, and as the lower valve, &c., can be got at from the surface, the hole can be filled up again.

"It will be seen that this plan will frequently be found the most economical, especially where it is not known beforehand that the water will require to be raised from such a depth, as it enables the small tube that has been driven to be utilized, instead of having to pull it up, and re-drive another larger and more expensive tube, besides the delay thereby incurred.

"When water is required in large quantities, either for public establishments, factories, breweries, or for irrigation, two or more of the first, second, or third sized wells are driven, and coupled together to one main, according to the supply required and the nature of the strata from which the supply is obtained.

"No rule whatever can be laid down as to the number or size of tube wells necessary to be driven in order to obtain a given quantity of water, for everything depends upon the nature of the water-bearing strata. In some places water may exist in abun-

dance, but the stratum may be of a close, unyielding nature; in other places the water-bearing seam may be but shallow, and yet supply a copious yield, and in others both the seam may be shallow and the yield slow, and *vice versâ*.

"The smallest size tube well ($1\frac{1}{4}$-inch) is of course the most handy, and when the supply required is not very large, it may be more convenient to couple as many as four or five together, though this remark refers more particularly to when the wells are sent to colonies and great distances, where it would involve considerable delay to send for the larger sizes. The average $1\frac{1}{4}$-inch well will yield from 150 to 800 gallons per hour, according to the nature of strata and power applied.

"The second size (2-inch) is a very useful one, and can at times be used with advantage to the number of 10 or 12 coupled to one main, the capacity of yield being from 300 to 1,500 gallons per hour, according to the nature of the stratum, &c.

"The third size (3-inch) is the description mostly employed for large supplies, and on an average will yield from 450 to 2,000 gallons per hour.

"It should be mentioned that in localities where the yield is found to be slow, and the water-bearing seam shallow, it is sometimes an advantage to employ a larger number of small wells in preference to a lesser number of large wells, inasmuch as if the rate of supply will not exceed a given maximum quantity to one centre, the employment of larger wells will not increase such yield proportionately with the increased size.

"The manner in which a number of these wells are usually coupled together is by means of a main, or series of cast iron flange pipes with branch pieces placed at intervals, such intervals being governed by the nature of the water bearing seam. Usually it is found that 18 feet of main is a fair space to place between the branch pieces in order that the draught of one well may not interfere with that of the next. There are, of course, places where it would be safe to place them nearer together, whilst on the other hand there are places where it may be necessary to increase this distance. As a rule the further apart (within reason) the better.

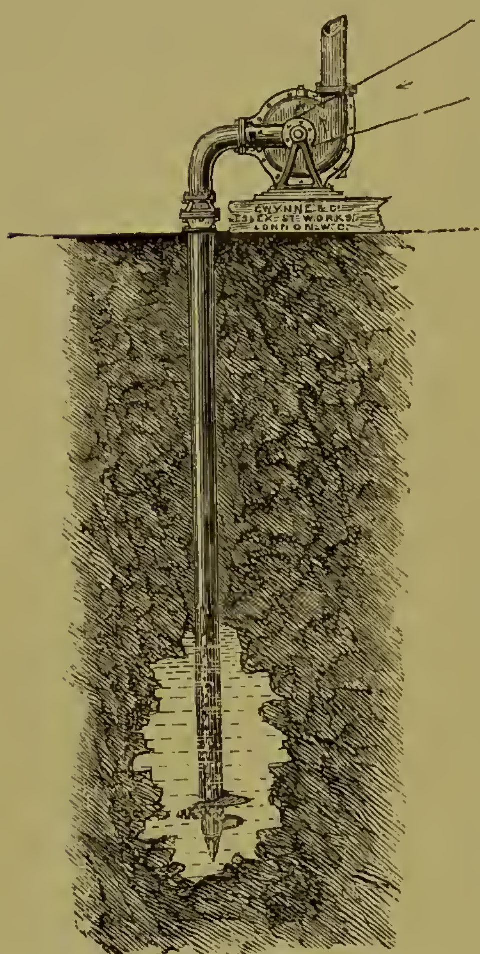
"As will be seen by Fig. 85 a bend is attached to each branch piece, and this bend is coupled on to the tube well by means of a flange screwed on to the tube well corresponding with the flange of the bend.

FIG. 85.

"More wells can always be added to this main at any time by simply substituting a branch piece for the terminal bend, and prolonging the cast iron pipes in accordance with the number of wells added, and again finishing with the original terminal bend.

"For convenience and protection from frost it is customary to lay these mains two feet below the surface. The flange joints are usually made with india-rubber washers."

FIG. 86.




The makers of these tube wells state that in gravel, chalk, and some kinds of hard marls, from 400 to 2,000 gallons of water per hour may be obtained by their use, the ordinary quantity in coarse sands ranging from 300 to 800 gallons per hour, and in fine sands (including quicksand and loamy sand) from 150 to 500 gallons per hour. At Burton-on-Trent where the coupled tube wells—which are shown by Fig. 85—are in use, and where the subsoil is composed of a gravel and sand, two of the principal brewers raise from 40,000 to 60,000 gallons per hour each. At Northfleet (cement works) 3,000 gallons per hour are thus raised from the chalk, and at Newark 4,000 gallons per hour from the red marl formation. There is no reason why such a safe and economical means of supply should not be more frequently resorted to for dwellings of all kinds where the water stands in the ground within a moderate distance of the surface.

Fig. 86 shows a tube well and centrifugal pump adopted by Messrs. Gwynne, and recommended by them where a large supply is to be raised from an underground bed of water within ready reach. The pipe or tube selected has a powerful screw attached to it; this is turned round and screwed into the ground. If the tube is large in diameter, a windlass or horse-power may be required to sink it, and in such cases it may be necessary to leave the end open so as to reduce the friction and the consequent power necessary for sinking. Fig. 86 shows the tube sunk to a proper depth in the water-bearing strata. A series of holes or

openings is left in the lower end of the tube, a powerful sucking pump is applied to the upper end of it, and the water comes up, bringing with it sand, clay, &c.; this after a time makes a cavity, as shown, which acts as a reservoir for the water, and the more such wells are worked the better they will become. This mode of sinking, especially through quicksand, or where large quantities of surface water have to be contended with, offers highly important advantages.

LXVIII.—Rain-water from Roofs and Impervious Surfaces.—The collection of water from clean roofs can hardly be over-valued if, as declared by Dr. Angus Smith, and satisfactorily proved in many cases, the rainfall can positively be preserved free of organic impurities, and raised to the highest standard of quality by careful collection and judicious domestic filtration.

There are many dwellings—public institutions and mansions—in this country where the extent of roofing exceeds in superficial area half an acre, or 80 poles (600 × 33 feet), and very many more—mansions, for instance—where it exceeds a quarter of an acre, or 40 poles. An ordinary dwelling-house will cover 10 poles, and a rural labourer's cottage $2\frac{1}{2}$ poles.

An inch of rain falling on these surfaces will yield respectively 11,311 gallons, $5,655\frac{1}{2}$ gallons, $1,413\frac{3}{4}$ gallons, and $353\frac{1}{2}$ gallons. On the western side of the country the *minimum* annual rainfall reaches 25 inches; on the eastern 15 inches. If the whole of these minimum quantities be collected they would amount to (1) 282,775 gallons, (2) 141,387 gallons, (3) 35,347 gallons, and (4) 8,837 gallons respectively on the west; and on the east to (1) 169,665 gallons, (2) 84,832 gallons, (3) 21,208 gallons, and (4) 5,302 gallons. From this it will be seen that, taking the domestic supply per person at 15 gallons per diem, the quantity to be secured would be sufficient in the west for 50 persons, 25 persons, 6 persons, and $1\frac{1}{2}$ persons respectively, and in the east for 30 persons, 15 persons, 4 persons, and 1 person respectively, all the year round, and, of course, to three times as many if, instead of 15 gallons a head, 5 gallons would suffice, which in times of drought it would probably do.

Where the quantity of water required is in excess of that which roofs will afford, it will be necessary to add an extent of surface, which may be prepared by covering the ground with concrete or other impervious material to throw off the required addition. A few poles of ground with a regular slope will frequently suffice for this purpose.

LXIX.—Water from the Surfaces and from the Under-drains of Cultivated Lands.—The water from cultivated surfaces, in which is included that which is contributed to our

rivers by tributary streams, and which may have been rendered impure by the organic matter washed off such surfaces, is generally inferior in quality to that to be obtained from roofs and prepared surfaces. Nor is the water obtained from the surface of cultivated lands so good in quality as that placed at command by the under-drains of such lands. The quantity available in a year from the under-drains of clay lands will probably amount to one-third of the winter's rainfall, but the minimum discharge, upon which alone dependence can be placed, may be as little as one inch, or 22,622 gallons per acre. With this reduced supply, if supported by proper storage arrangements, two-and-a-half acres of land will suffice for the supply of a dwelling, containing 10 persons, with 15 gallons per head per diem for a whole year.

Water thrown off cultivated surfaces may be made serviceable for use, where other means of supply fail, by simple filtration through natural soil. Thus it may become very far superior to the water now consumed by the majority of households in rural districts. The preparation of the filter beds of natural soil through which to run these waters is simple enough. A plot of land by the side of a stream may for convenience be selected for the purpose. It must be under-drained as deeply as possible, and the water being diverted from the stream should be evenly distributed over its surface, and if the distribution be regulated by furrows, it may be effected with precision.

The water of under-drainage, if found to contain ingredients of an objectionable character after its passage through the ground to the under-drains, can be rendered perfectly unobjectionable by a second filtration through a plot of prepared soil, as pointed out in the case of surface waters.

Objections have been advanced to the use of any water that may have been once impure; but when we are taught by chemists to believe that the extraordinary purifying powers of aërated soil will render innocuous large quantities of sewage in which exists organic nitrogen in considerable amount, we must be satisfied that by a second passage through natural soil, the water of under-drainage may be positively freed from any injurious ingredients it may have contained. The advantage of filtration through soil has been shown at Merthyr Tydfil, where the effluent water of the under-drains of the land to which sewage was applied was found by the analyses of the Rivers Pollution Commission to contain, on an average, not more than ·032 parts of organic nitrogen per 100,000 parts of water.

## CONTENTS OF CHAPTER IX.

### MOTIVE POWERS TO RAISE WATER FOR THE SUPPLY OF DWELLINGS.



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# CHAPTER IX.

LXX.—Introductory Observations.—Having referred to the several sources from whence a supply of water may be gained for the dwelling, it should be now considered by what means the quantity required for use may be most economically delivered to it—whether, failing gravitation, the power necessary for the purpose shall be exerted by hand, horse, wind, water, steam, gas, or hot air.

The choice will necessarily depend upon the depth from which the water has to be lifted, the height to which it has to be raised, the rate at which it must be delivered, and the total quantity required for use. The power afforded by steam may be said to be always at command and to be unlimited; with other motors the power afforded will be dependent upon local circumstances.

To arrive at the value of manual and animal power, Telford adopted the rule that "the work done by an animal is greater when the velocity with which it moves is one-third of the greatest velocity with which it can move when not impeded, and the force then exerted is four-ninths of the utmost force the animal can exert at a dead pull." He considered that a man of ordinary strength could exert a force of 15 lbs. at a crane handle moving at the rate of 220 feet per minute per day of eight hours, while an ordinary horse when drawing at the same speed—220 feet per minute—would be able to exert a steady pull of 150 lbs. for eight hours per day—$220 \times 150 = 33{,}000$ foot pounds per minute. At this rate a horse is equal to ten men.

I give this here, as the power to raise 33,000 lbs. to a height of one foot per minute is that which is now generally taken, as is well known, as the datum power of a horse in calculations of the service of different motors.

Boulton and Watt arrived at the same result in a different way, though they considered that the power of a horse was only 5½ times that of a man.

The usual calculation is that an average horse has seven times the power of an average man—a proportion which will be found to agree with the figures given in the following useful table of *Power required to raise Water from Deep Wells*, from Molesworth's book of *Engineering Formulæ*:—

| Diameter of pump barrel. | Description of pump. | Quantity of water raised per hour. | Maximum depth from which this quantity can be raised by each unit of power. | | | |
|---|---|---|---|---|---|---|
| | | | One man turning a crank. | One donkey working a gin. | One horse (animal) working a gin. | One horse-power steam engine. |
| Inches. | | Gallons. | Feet. | Feet. | Feet. | Feet. |
| 2 | Double-action lift and force pump. | 225 | 80 | 160 | 560 | 880 |
| 2½ | | 360 | 50 | 100 | 350 | 550 |
| 3 | | 520 | 35 | 70 | 245 | 385 |
| 3½ | | 700 | 25 | 50 | 175 | 275 |
| 4 | | 900 | 20 | 40 | 140 | 220 |

A gallon of water weights 10 lbs., and by the data given it will be seen that the maximum number of gallons which can be raised by an average horse one foot high per hour reaches 198,000 gallons, and by an average man 28,286 gallons.

In practice a considerable allowance must be made for the loss of power resulting from friction, and from the inappropriate or defective nature of the machinery by which the power is utilized. It may be well, therefore, to explain the different mechanical arrangements which are usually adopted in the raising of water, and before doing so to give here some deductions made from certain details which I have obtained from several of our principal mechanical engineers—Messrs. Gwynne, Essex Street; Messrs. Owens and Co., Messrs. Warner, Messrs. Tangye, and Mr. Mason, Ipswich;—and which I have reduced to the form of the following table, showing when hand, horse, or steam power (or its equivalent in wind or water) can be most economically adopted.

TABLE showing the description of pump to be adopted, the character of power required, and the time taken to raise different quantities of water from various depths below, to a height of 60 feet above, the surface of the ground for the supply of dwellings.

| Depth of water from surface of ground. | Total quantity of water required to be raised daily. | Description of pump to be used. | | | Character of power to be employed. | Quantity raised in one hour. | Time taken to raise the total quantity. |
|---|---|---|---|---|---|---|---|
| | | Character. | Number of barrels. | Length of stroke. | | | |
| Ft. | Galls. | | | Inches. | | Galls. | Hrs. |
| 25 | 250 | 2½″ lift and force pump | 1 | 6 to 9 | One man or strong boy | 170 | 1½ |
| | 1,000 | 3″ ditto. | 2 | 7 to 9 | Two men or donkey | 340 | 3 |
| | 5,000 | 4″ ditto. | 3 | 9 to 10 | One horse ... ... | 1,000 | 5 |
| | 25,000 | 6″ ditto. | 3 | 12 to 18 | 3 H.P. engine ... | 5,000 | 5 |
| | 50,000 | 7½″ ditto. | 3 | 18 to 21 | 4 H.P. engine ... | 10,000 | 5 |
| 60 | 250 | 2½″ ditto. | 1 | 6 to 9 | One man or strong boy | 125 | 2 |
| | 1,000 | 3″ ditto. | 2 | 9 | Donkey or pony ... | 500 | 2 |
| | 5,000 | 4″ ditto. | 3 | 9 to 12 | Two horses ... | 1,000 | 5 |
| | | | | | 2 H.P. engine ... | 1,500 | 3⅓ |
| | 25,000 | 6″ ditto. | 3 | 12 to 18 | 4 H.P. engine ... | 5,000 | 5 |
| | 50,000 | 7½″ ditto. | 3 | 18 to 21 | 6 H.P. engine ... | 10,000 | 5 |
| 100 | 250 | 2½″ ditto. | 1 | 7 | One man ... ... | 100 | 2½ |
| | 1,000 | 3″ ditto. | 3 | 9 | One horse ... ... | 400 | 2½ |
| | 5,000 | 4″ ditto. | 3 | 9 or 10 | Two horses ... | 1,000 | 5 |
| | | | | | 2 H.P. engine ... | 1,500 | 3⅓ |
| | 25,000 | 6″ ditto. | 3 | 12 to 18 | 6 H.P. engine .. | 5,000 | 5 |
| | 50,000 | 9″ ditto. | 3 | 18 | 12 H.P. engine ... | 10,000 | 5 |
| 200 | 1,000 | 3″ ditto. | 3 | 9 | Two horses ... | 400 | 2½ |
| | | | | | 2 H.P. engine ... | 800 | 1¼ |
| | 5,000 | 4″ ditto. | 3 | 9 | 2 H.P. engine ... | 1,000 | 5 |
| | 25,000 | 6″ ditto. | 3 | 15 to 18 | 8 H.P. engine ... | 5,000 | 5 |
| | 50,000 | 9″ ditto. | 3 | 18 | 12 H.P. engine ... | 10,000 | 5 |
| 300 | 1,000 | 3″ ditto. | 3 | 12 | 2 H.P. engine ... | 700 | 1½ |
| | 5,000 | 4″ ditto. | 3 | 12 | 4 H.P. engine ... | 1,500 | 3⅓ |
| | 25,000 | 6″ ditto. | 3 | 15 to 18 | 8 H.P. engine ... | 4,000 | 6¼ |
| | 50,000 | 9″ ditto. | 3 | 18 | 14 H.P. engine ... | 7,200 | 7 |

In these figures it has been assumed that the water required has to be lifted to a height of 60 feet above the surface in each case. Where, in addition to this height, the depth of the water beneath the surface does not exceed 25 feet, it would appear from the foregoing table that 170 gallons an hour will represent the extent of a man's power, while two men may raise double this quantity, and a horse 1,000 gallons.

With a depth of 50 or 60 feet beneath the surface, a man may raise the water at the rate of about 125 gallons an hour, and a donkey will raise as much as 500 gallons, a superior power having to be resorted to as the rate of delivery is increased.

With the water at a depth of 100 feet from the surface, a man may still be economically employed if the rate of delivery need not exceed 100 gallons an hour, and a horse will be available for

quantities between this and 400 or 500 gallons. Beyond this latter rate, however, it will be desirable to resort to steam.

With water at a depth of 200 feet below the surface, both manual and animal power will give way to mechanical power as the more economical.

LXXI.—Manual Power.—Leaving the pump itself to be dealt with presently, there is little to be said upon the arrangements by which manual power can be economically utilized. Where the depth from which the water is lifted does not exceed 25 feet, and the quantity of water used daily does not exceed 500 gallons, the common atmospheric, *i.e.*, the suction or lift-pump, with its levered handle, is the best and cheapest. (*See* Chapter X, Section LXXVIII.)

Where the quantity to be raised is comparatively large and the depth considerable, the levered handle must give way to a framed arrangement of gearing which can be worked by wheel and pinion, and which readily allows of the employment of either one or two men as required. Examples of two different forms in which this arrangement may be adopted are shown by Fig. 87, and in a somewhat larger form by Fig. 88.

Fig. 87.

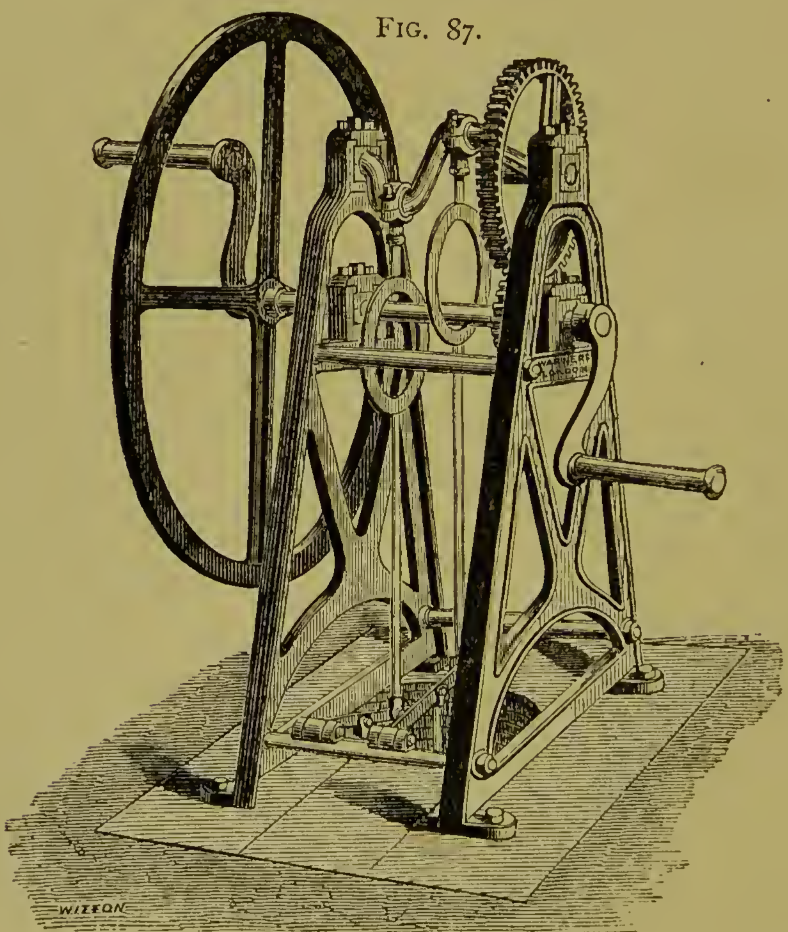
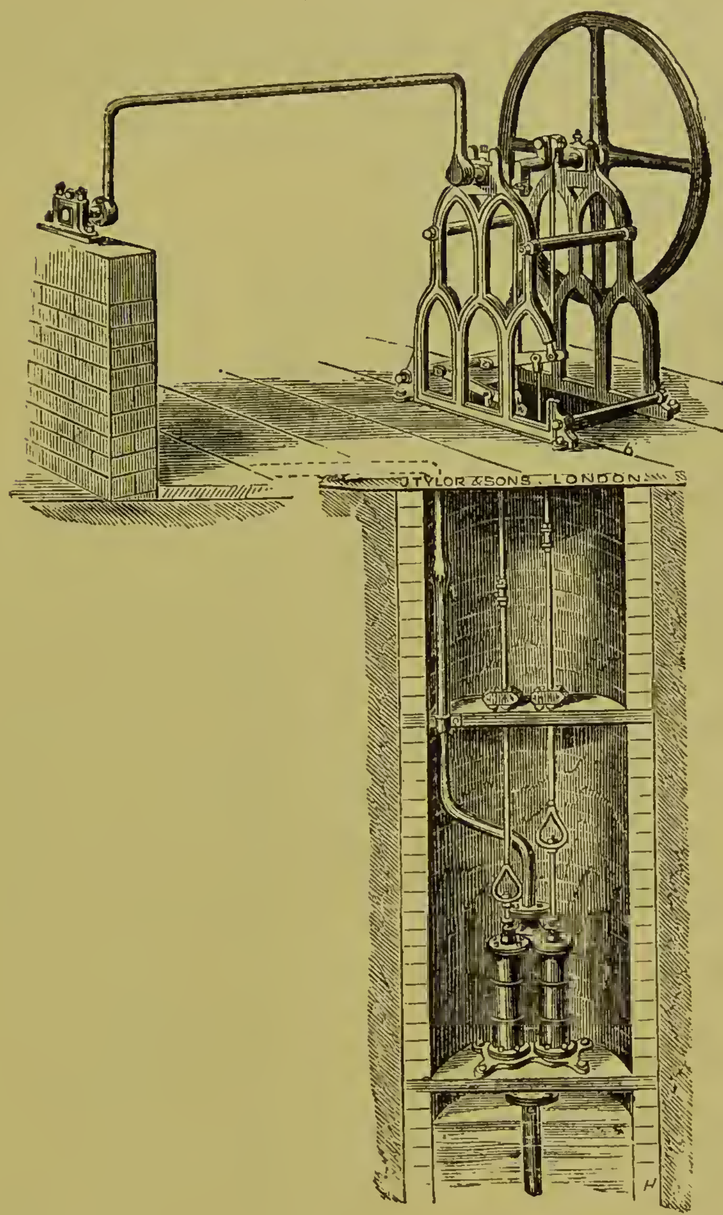


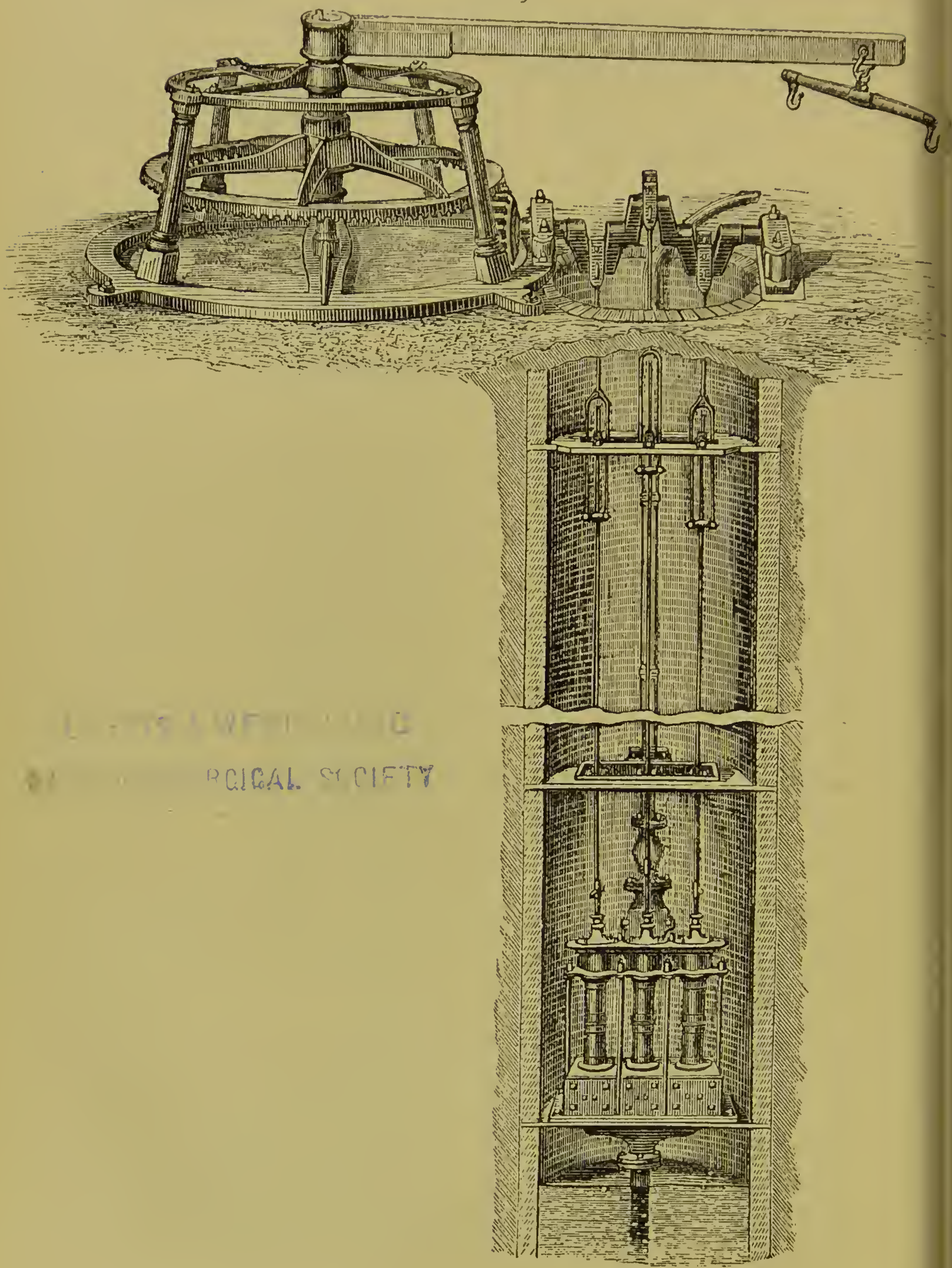
FIG. 88.




There are also various other forms for the employment of a number of men, as is frequently the case in workhouses and prisons, but which it is unnecessary to illustrate here.

LXXII.—HORSE POWER.—The gearing necessary for the application of animal (horse) power to the raising of water by pumps requires but little explanation. One example of such gearing and its connection with a three-throw pump as shown by Fig. 89 will be sufficient. By means of different sized cog-wheels the speed of the pumps may be regulated and the slower pace of one animal compared with another overcome. The gearing may be placed either directly over the well or by the side of it as in the illustration, and may be put either above the ground level

Fig. 89.



or below it, with the shaft only, to which the horse is attached, raised above the ground. The horse-power arrangement should be where practicable from 25 to 30 feet in diameter, though a horse will walk without discomfort in a circle of 18 or 20 feet.

LXXIII.—WIND POWER.—There is every reason to believe that in raising underground water from a considerable depth the neglected power of wind will come into more extended use again for large establishments, supplemented as it always can be by steam or horse-power when the wind fails. Wind was at one time very commonly utilized in this country. It gave way to water as the more certain, and water in its turn gave way to steam as the most manageable of all motive powers. Now, however, that coal is expensive and water is in demand for many purposes for which steam has been used, attention is again, though slowly, being paid to wind, and the ingenuity of the engineer is now frequently sought to furnish the most economical form of wind engine. Very good specimens are made by Messrs. Owens and Co., Messrs. Gwynne and Co., and Messrs. Warner.

FIG. 90.

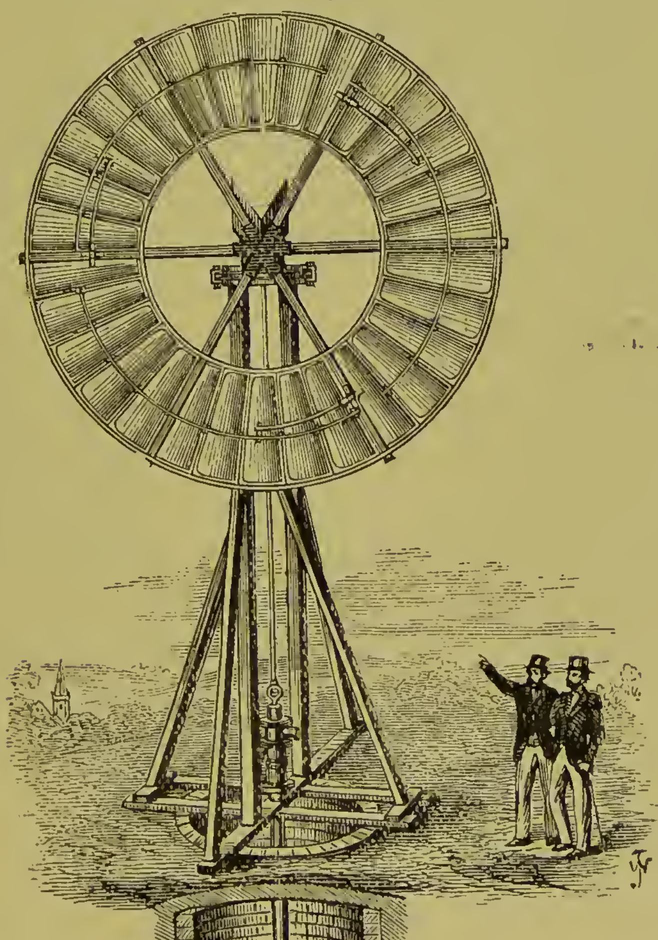
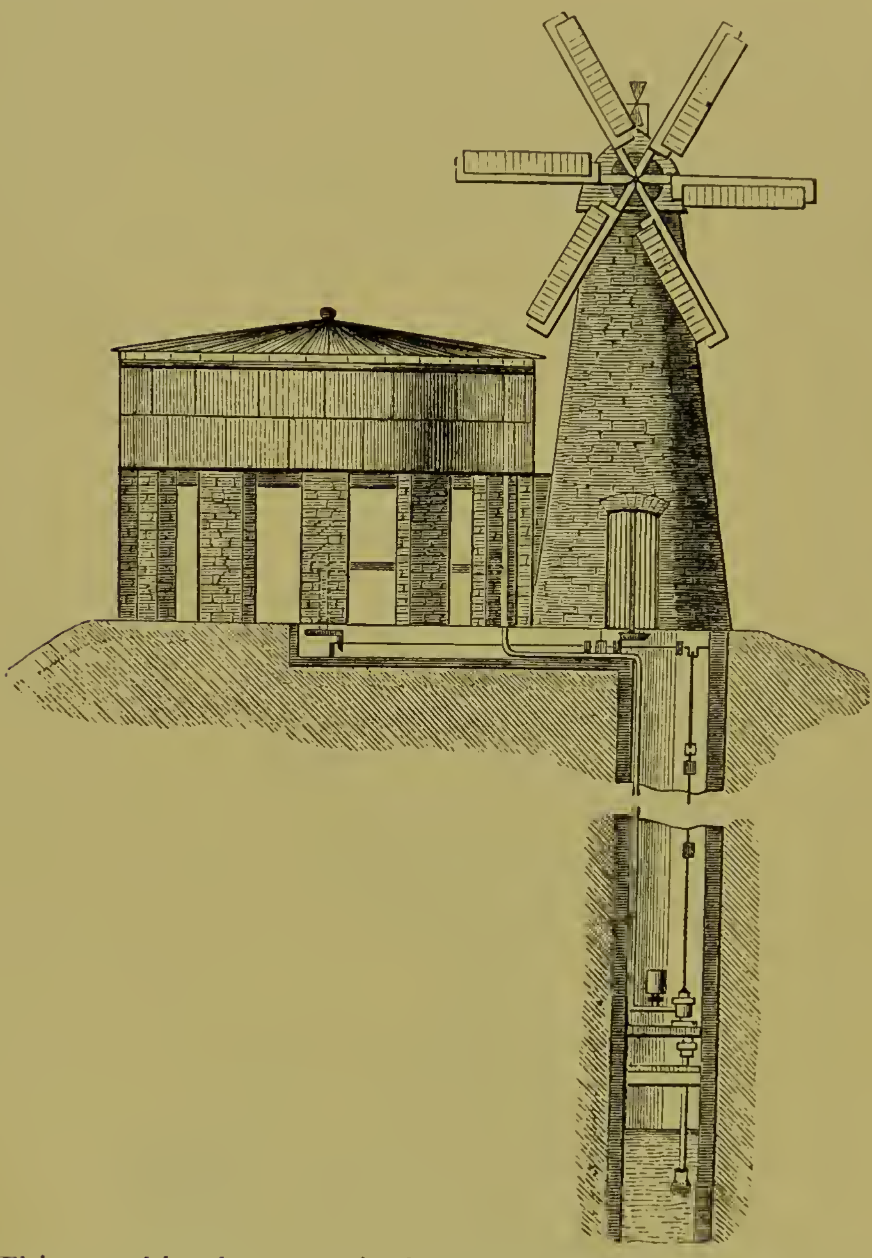


Fig. 90 shows the simplest form of wind engine, in its cheapest form, without a brick tower as manufactured by this last named firm; while Fig. 91 illustrates how wind may be utilized, as stated above, either in conjunction with animal (horse) power, or with a small steam-engine (either the one or the other being worked instead of wind as occasion necessitates).

FIG. 91.



This combination, as will be understood by the illustration, entails additional outlay; it may frequently, however, in large country dwellings, be worked with advantage, if motive power is required for other household purposes, in addition to the raising of water.

The extreme number of days in a year on which the wind might not have sufficient power to perform the required duty has been stated to be less than 100 days, but any estimate to be of value must depend so much on local circumstances, that this must be taken with reservation.

An absence of wind would seldom last more than a fortnight at a time, and seeing that the service tank of any large establishment, and, indeed, of any village may be made to hold a quantity sufficient for a fixed number of days or weeks, and that the wind when at work would do duty during the night as well as the day, it may be fairly assumed that recourse to supplemental power would not be very frequent, and that when the wind fails recourse to horse (animal) power for a few hours occasionally would be sufficient.

It must be granted that the great drawback to the general adoption of wind for such work lies in the fact that it is erratic, and that the engine is subject to derangement on its sudden violence.

LXXIV.—WATER POWER.—The readiest means that can be used for raising water from running streams or springs is the water itself. Where it exists in quality sufficiently pure for domestic use, and in quantity sufficient to be used as a power at the same time, the hydraulic ram will be found to be the cheapest and best motor, though the wheel and the turbine have each superior advantages where such special conditions do not exist.

(1.) *The Ram.*—Where the quantity of water is small and its quality perfectly pure, and where the elevation to which the water has to be raised is not too great, the hydraulic ram commends itself as the most economical of all water-lifting machines. An ordinary ram with a fall, for instance, of 8 feet, and with a flow of water to it of 38 gallons per minute, will raise 4,000 gallons per diem, from 40 to 50 feet in height to a distance of half-a-mile.

The principle of the ram is different to that of any other hydraulic machine, as by concentrating into a small quantity the force accumulated by the motion of a larger body the small quantity is raised to the required height. The fall to the ram should in no case exceed 20 feet, or repair will be frequently needed. As the hydraulic ram differs in its principle of action from all other means of raising water, so its useful effect varies according to a different law. For instance, when the height to which it is desired to lift the water amounts to eight times the fall which works it, the useful effect will be 66 per cent., but when the elevation is ten times the fall, the useful effect will be reduced to 50 per cent., while at twenty times the fall, the useful effect will be only 18 per cent.

An illustration of an improved hydraulic ram, combining the action of a pump with that of the ordinary ram, is shown by Fig. 92. Here, if the water working the ram is impure, and pure water is readily obtainable from a lower level, the latter may be drawn up by means of the suction pipe C, and conveyed by discharge pipe D to point of delivery.

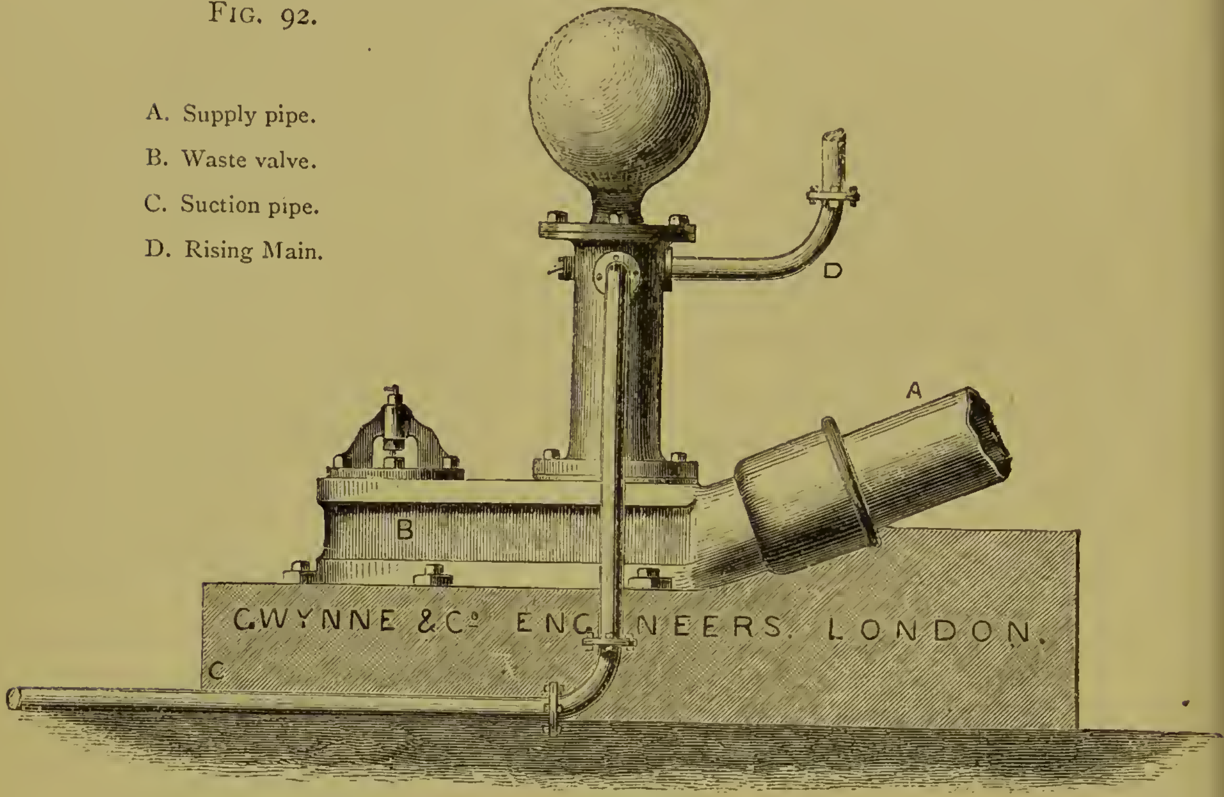
FIG. 92.

A. Supply pipe.

B. Waste valve.

C. Suction pipe.

D. Rising Main.



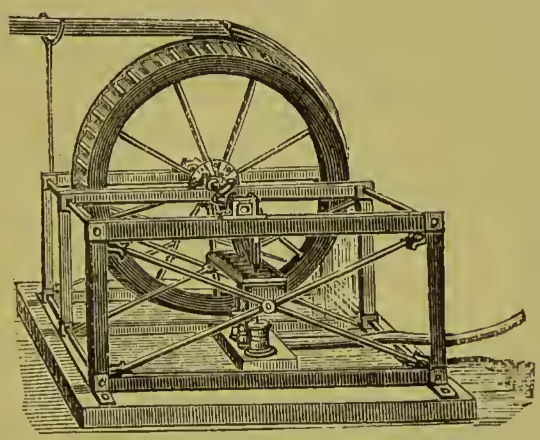

A ram very suitable in cases of isolated dwellings has been introduced into this country from America, and is known as the Douglas Ram. Its action will be readily understood by the following reference to the case of Lea Hall—a farmhouse in Cheshire. The water used at this place is lifted from a stream which has been dammed up so as to give a head or fall of 8 feet 6 inches. From this stream a volume of water equal to about 25 gallons per minute flows into the ram. Of this quantity about one-eighth is delivered to the farmhouse and buildings, which lie at a height of 50 feet above, and a distance of about 100 yards from the ram. This ram is stated to be applicable where no more than 18 inches of fall can be had, though the greater the fall, within moderate limits, the more effective will be the result. It is also stated that a fall of 10 feet is sufficient to raise water to any elevation under 150 feet, and that in conveying it to a distance of 50 or 60 yards it may be calculated that about one-seventh of the water can be raised and discharged at an elevation above the ram five times the height of the fall working it.

A ram performs its task with very little care on the part of its owner, except to see that the water is strained through a grating before passing through the ram, and that it is emptied or protected during a hard frost.

(2.) *The Wheel.*—The principle of the water-wheel is so well understood that it need only be referred to in brief terms. In doing so, however, its importance in the water supply of the dwelling should not be underrated, for there are many institutions and country mansions in close proximity to running streams the waters of which may, by means of its use, be favourably and inexpensively employed for various domestic purposes. Water-wheels, however, for obvious reasons, are not to be depended on in cases where the stream is liable to frequent floods.

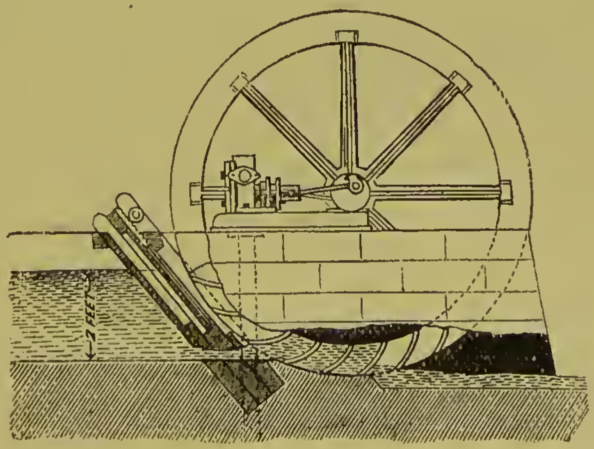
During recent years the water-wheel has undergone many improvements, and wood has greatly given way in its construction to iron and other metal. The wheel known as the overshot wheel (*see* Fig. 93) gives a greater power than any other form where the

FIG. 93.



fall is comparatively great, and the quantity of water available to work it is small Where, as will be the case in the majority of

FIG. 94.



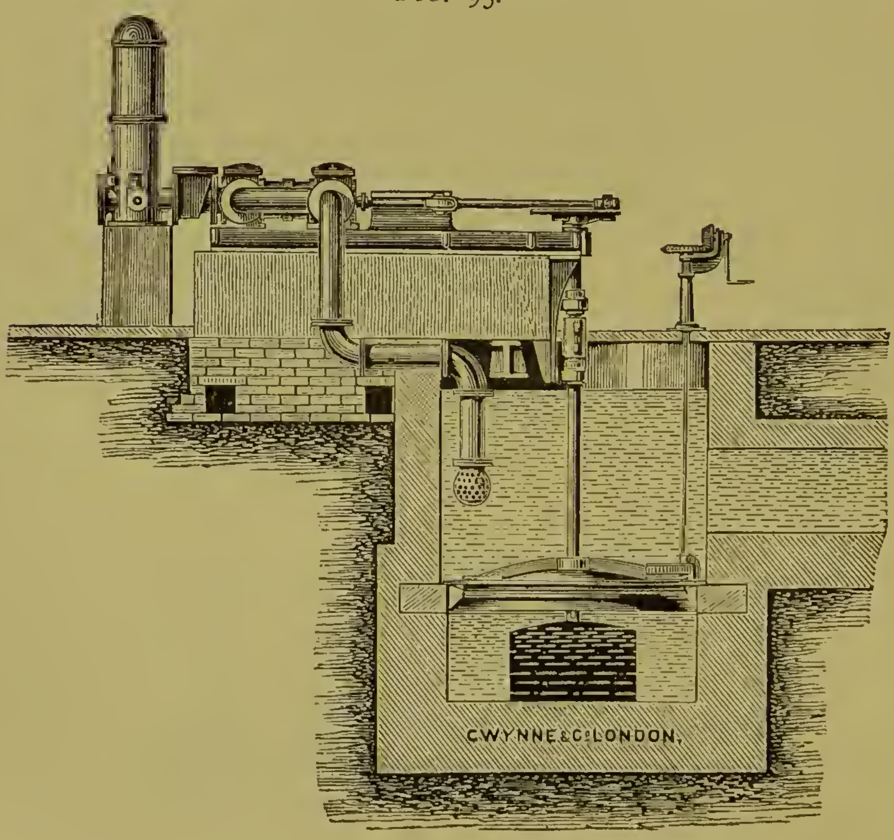
instances, the river or stream at command has but a slight inclination, and where therefore the overshot wheel could not be adopted, the undershot wheel will be found serviceable (*see* Fig. 94). Between the two extremes the breast wheel may be turned to better account.

Comparing the undershot wheel with the overshot, the relative efficiency of the latter may be taken to be about double that of the former, while the breast wheel will yield a result rather greater than the mean of the two.

(3.) *The Turbine.*—The turbine has of late years undergone many improvements, and M. Fourneyron has done much towards its present perfection. M. Girard, of Paris, who unfortunately was killed at the last siege of that city, also spent much time in the improvement of the turbine, and the machines which have been constructed upon his design are amongst the best we have. No machine, however, requires more absolute perfection in its proportions to give a good result, and many that are sold are very far from being fully effective owing to imperfect design or construction. Turbines, unlike the water-wheel, are applicable where the available head of water is frequently varied.

On a large scale very high results have been obtained, but for small applications 70 per cent. only of the power expended may be considered the limit of perfection, while from this there must be

FIG. 95.



a further deduction due to the pump and gearing which will reduce the product to 50 per cent.

Messrs. Gwynne, of Essex Street, Strand, have designed several machines in which they connect the turbine with all kinds of pumping machinery. For low lifts, say 20 feet, they combine the turbine with the centrifugal pump. This arrangement is suitable for a low fall, and from its simplicity requires but little attention. Fig. 95 shows a turbine also suitable for a low fall, say of 4 feet, but working a high lift pump to deliver at an elevation of 50 to 100 feet at a long distance from the turbine itself.

This, Messrs. Gwynne say, is the simplest arrangement possible, as there is no intermediate gearing. It produces also an excellent result. There are also various other forms of turbines by different makers, both suitable for considerable fall, and working various kinds of pumps.

LXXV.—Steam Power.—Steam, unlike wind or water, used as motive power, possesses the advantage of being capable of application to any extent at any time. It has the disadvantage, however, of not only involving a comparatively heavy first outlay, but of requiring the provision of skilled attendance, and of necessitating a constant expenditure in fuel, &c., though this latter item may in many cases be reduced by the provision of storage reservoirs or tanks, when the engine need only then be used two or three times a week. In all cases where the power required is great, steam will form the most suitable motor, and many excellent machines are now made which may be used either in combination with the ordinary lift and force pump, or with the more modern centrifugal pump.

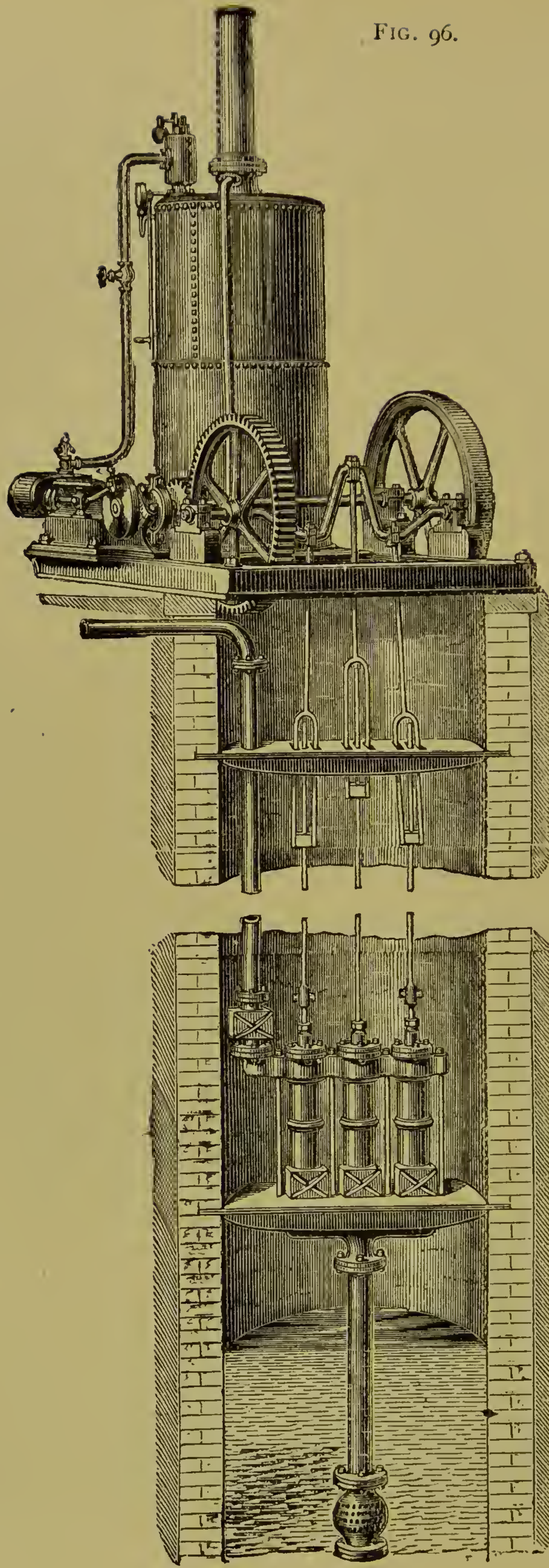
It is not here proposed to go into the constructive principles of these engines.

In many large establishments in rural districts, steam power may be required for other purposes than water supply. In such cases the familiar portable engine may be very advantageously adopted. It can be readily attached to, or detached from, the pumping machinery, and used for one purpose when not wanted for another.

Where a fixed steam engine is preferred it is not an uncommon practice to adopt a vertical arrangement similar to that shown, for instance, by Fig. 96, which represents one of Messrs. Tangye's engines, constructed on this plan.

Figs. 97 and 98 show the combined Centrifugal Pumping Engine of Messrs. Gwynne. Fig. 97 is a perspective view, showing a vertical suction to the pump, and Fig. 98 is an elevation of the pumping engine with a horizontal suction to the pump. A is the case of the pump; B the suction pipe; C the discharge pipe; D the steam cylinder driving the pump direct, without the

FIG. 96.



intervention of any gearing whatever; E is the steam pipe connected with the steam boiler; and F is the exhaust pipe from the engine. In these forms they are best suited for low lifts.

FIG. 97.

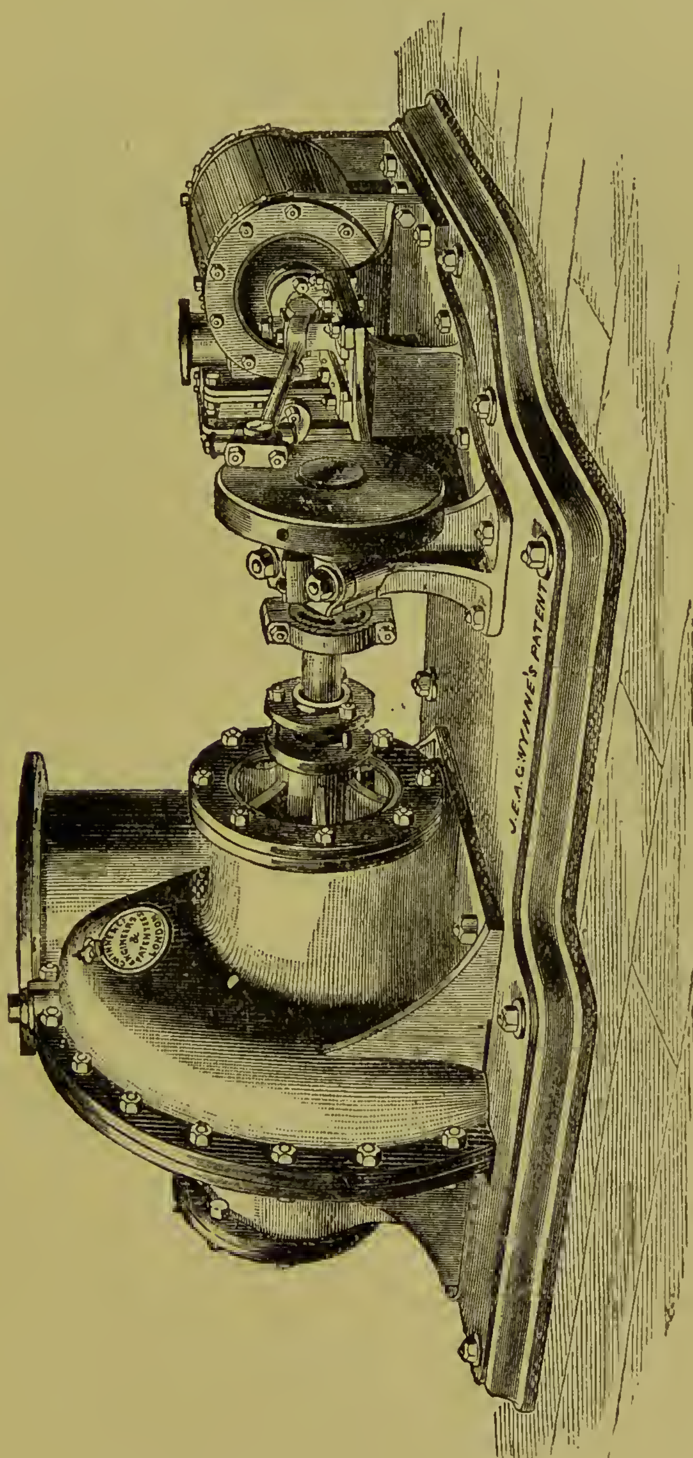


FIG. 98.

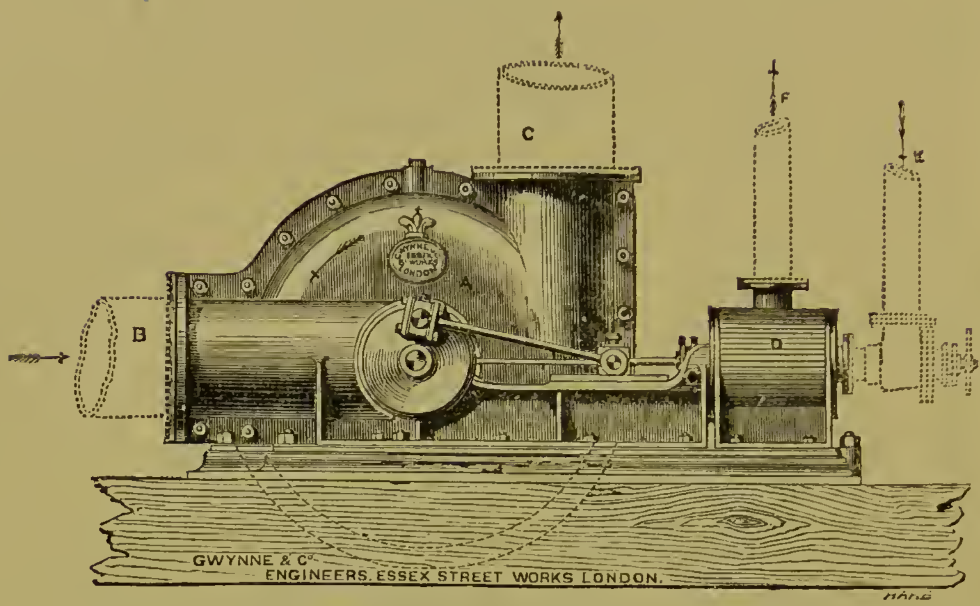
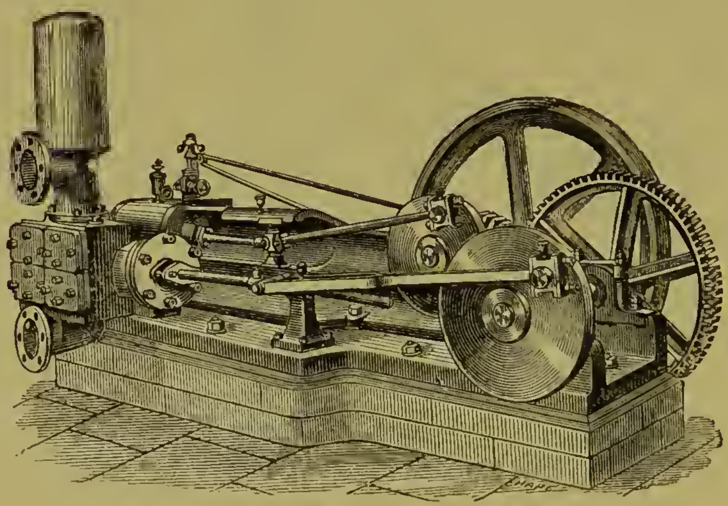



Fig. 99 represents a combined horizontal high pressure expansive steam engine and double action pump, manufactured by Messrs. Tangye.

FIG. 99.



LXXVI.—GAS POWER.—Gas is now frequently adopted as a motive power in the place of steam, and gas engines may, although up till now they have been principally used for trade purposes, with advantage be turned to account for raising water for the use of dwellings. Their special advantages consist in their requiring but little attention when at work, while in addition, owing to the absence of boilers, explosions from this cause are avoided, and, as there is no fire, the smoke nuisance is rendered impossible.

The consumption of gas by these engines is stated to be about 18 cubic feet per indicated horse power per hour.

FIG. 100.

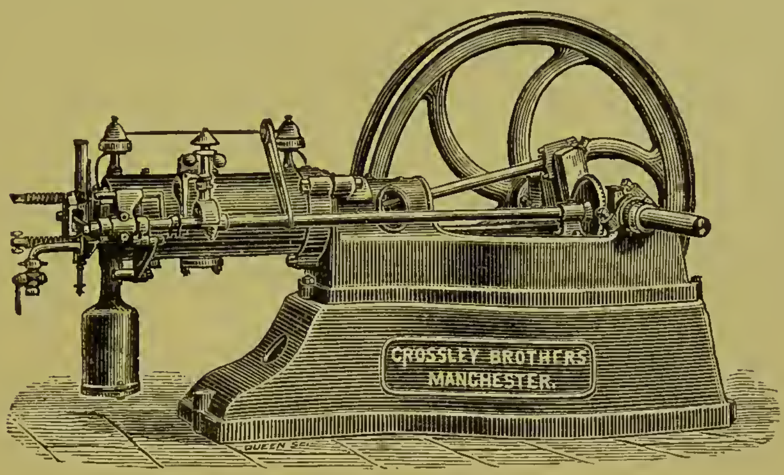



Fig. 100 shows one of Messrs. Crossley's "Otto Silent Gas Engines," the principle of which is thus described by them :—

"In it an explosion does not take place in the ordinary meaning of the term. A small part only of the charge is combustible, which on ignition serves to expand the remainder, thus avoiding shock and effecting great economy. The engine has also the peculiarity of igniting its charge at the *beginning* of the stroke, leaving the whole of the stroke for effective expansion of the gases, instead of merely a fraction, as in obsolete constructions.

"Every part of these engines is made to gauge, and is therefore easily replaced. The wearing portions are also of the simplest and most inexpensive patterns; for instance, the working barrel of the cylinder itself can be supplied for about $1\frac{1}{4}$ per cent. on the first cost of the engine, and being strictly to gauge, can be put on in a few hours.

"The pistons are of great length—of which the peculiar construction of the engine readily admits, and being also as light as possible, ride on the oil with the least degree of wear. They have now run for years without repair.

"The slide valves keep in excellent condition with proper care; but, as far as possible, to prevent risk of stoppage even from neglect, they are supplied in duplicate with each engine, except with the $\frac{1}{2}$-H.P. size, without extra charge.

"These engines will run with extreme smoothness and regularity of speed, and have very few working parts."

The sizes made are from $\frac{1}{2}$-H.P. to 16-H.P.

It appears, therefore, from experience gained when all attendant expenses are taken into consideration, that gas engines afford a

saving when compared with small steam engines, and that they will come more into general use for this reason.

LXXVII.—Hot Air Power.—Hot air is now taking its place as a motor for the raising of water for domestic purposes where a small power only is required. Hot air engines may be considered as perfectly safe, for, as in the case of gas, explosion is impossible; they are also extremely simple in their construction, having neither valve nor eccentric to get out of order, and like the gas-engine, they require no experienced engineer to look after them. They also possess the benefit of being noiseless, and a special feature in them is economy, coke being used in the place of coal.

Figs. 101 and 102 show the Rider Hot Air Engine.

Fig. 101.

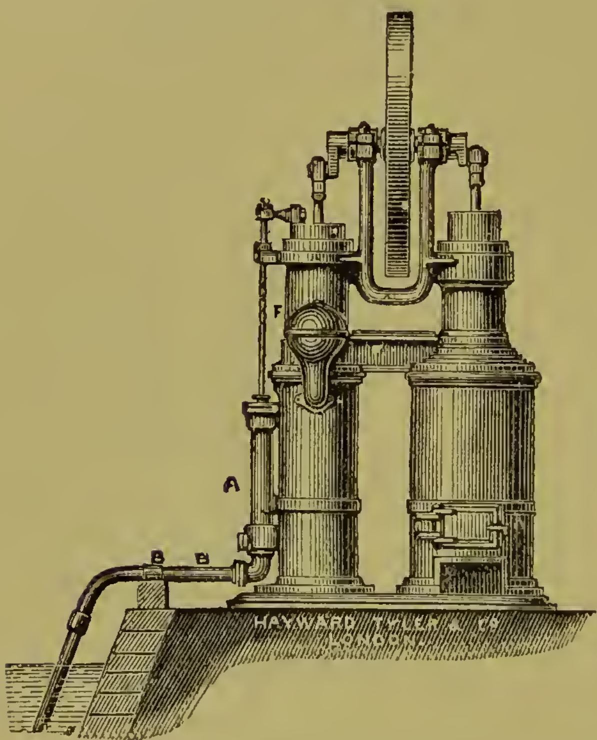
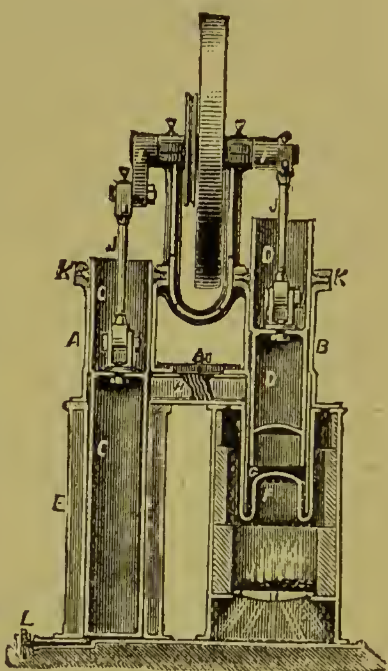



Fig. 102.




The sizes range from $\frac{1}{4}$-H.P. engine to a 2-H.P. The former will deliver into an ordinary house cistern about 200 gallons per hour, while the last-named size will deliver at least 1,000 gallons in the same time.

The mode of working the engine is thus described :—

"The compression piston C first compresses the cold air in the lower part of the compression cylinder A into about one-third its normal volume, when, by the advancing or upward motion of the power piston D, and the completion of the down stroke of the compression piston C, the air is transferred from the compression

cylinder A, through the regenerator H, and into the heater F, without appreciable change of volume. The result is a greater increase of pressure, corresponding to the increase of temperature, and this impels the power piston up to the end of its stroke. The pressure still remaining in the power cylinder and re-acting on the compression piston C, forces the latter upwards till it reaches nearly to the top of its stroke, when, by the cooling of the charge of air, the pressure falls to its minimum, the power piston descends, and the compression again begins. In the meantime the heated air, in passing through the regenerator, has left the greater portion of its heat in the regenerator plates, to be picked up and utilized on the return of the air towards the heater. This process recurs at each revolution.

"The same air is used continuously, as there is neither influx nor escape, the air being merely shifted from one cylinder to another.

"E represents a water jacket for the purpose of cooling the air more effectually.

"KK are the leather packings, which are in duplicate for each plunger. The lower one has its lap downwards to resist the escape of air below the piston, while the upper one has its lap upwards to prevent the lubricating material from entering too freely into the cylinders.

"Between them is the relief ring, which is so constructed as to almost entirely relieve the friction of the packings.

"L is a simple check valve which supplies any slight leakage of air which may occur. It is generally placed at the back of the engine, at the lower part of the compression cylinder, but is necessarily shown in the sectional cut on the side.

"When the engine is in perfect working order the check or 'suck in' valve L will only work for a few revolutions on starting the engine. Should the engine be found to draw in air continuously through this valve, it is a sure indication of leakage somewhere which should be stopped, otherwise a great loss of power will result.

It should be borne in mind that in frosty weather all the water should be drawn off from the cooler E and pipes to prevent their being burst by the frost."

## CONTENTS OF CHAPTER X.

### PUMPS.



---

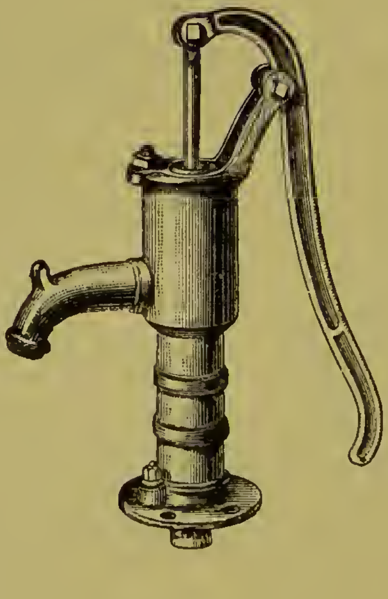
# CHAPTER X.

The pumps most suitable for the raising of water for the supply of dwellings from wells and tanks may be classified as follows: (1) the atmospheric or common suction pump; (2) the lift and force pump in its various forms; and (3) the centrifugal pump. Chain pumps (Norias) are only occasionally applicable.

LXXVIII.—Atmospheric or Common Suction Pump.—In practice it has been found that a depth of 28 feet is the limit from which water can be favourably drawn by this first class of pumps.

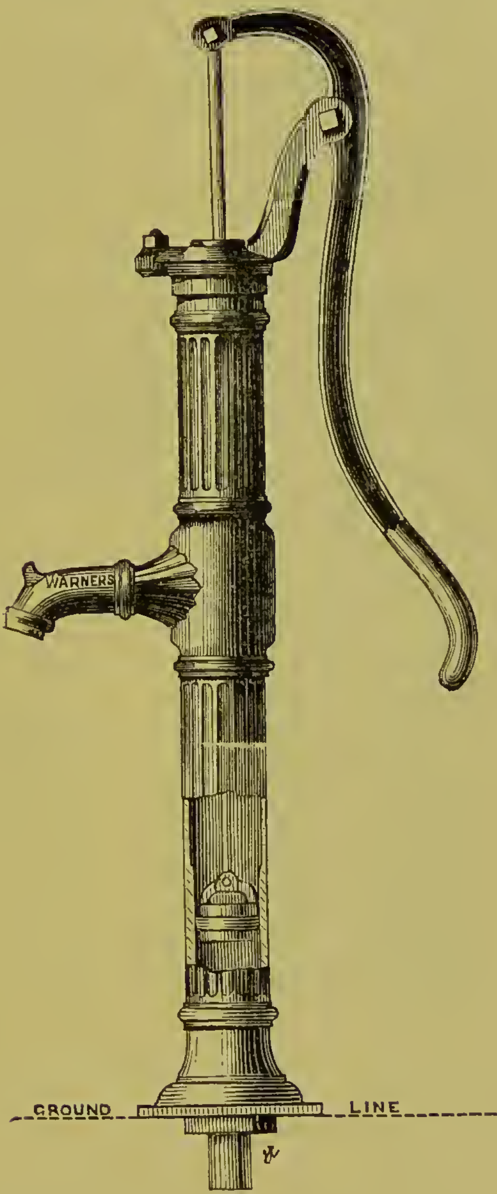
Fig. 103 shows a small suction pump made by Messrs. Tangye, and called their cottage pump, which is very suitable for erection within the dwelling itself, and can be placed over sinks and other

Fig. 103.



places where space and height are special objects; while Fig. 104 shows partly in elevation and partly in section, one of Warner's anti-freezing suction hand pumps, which can be erected out of doors for raising water from this limited depth.

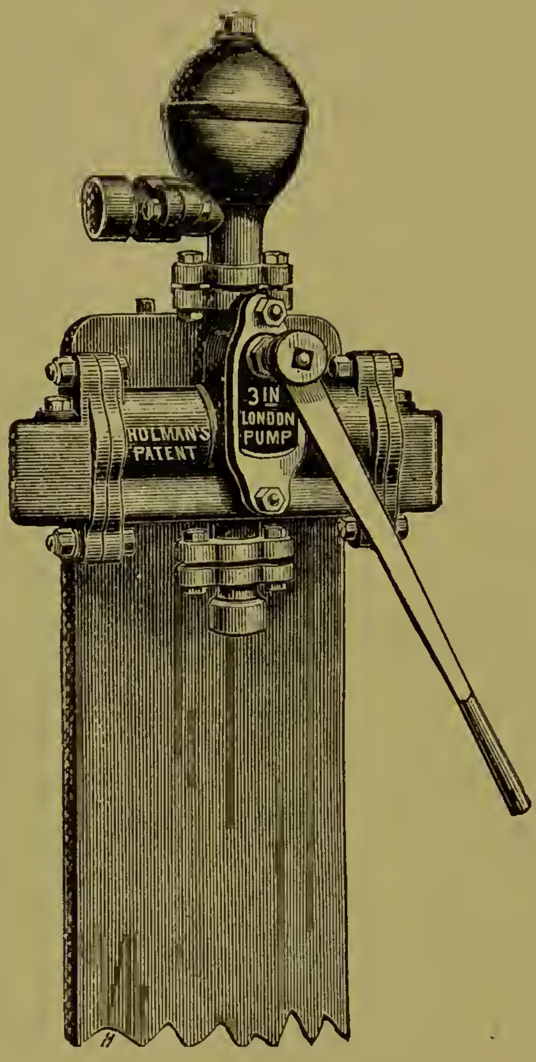
FIG. 104.




LXXIX.—LIFT AND FORCE PUMP.—Wherever the limit of 28 feet is exceeded, or where it is necessary to raise the water to any height above the surface of the ground, upward forcing power must be resorted to. In deep wells an arrangement is often adopted by which the water is forced up the rising main by the down stroke of the piston, but for ordinary purposes the suction power of the lift pump is combined as far as possible with the forcing power

which may be gained by the upstroke of the piston or bucket. These pumps are known as lift and force pumps. Fig. 105 shows

FIG. 105.




Holman's double action lift and force pump, which is very compact, occupying, as compared with others, very little space. It may be usefully erected within the dwelling for the supply of cisterns. It will be noticed from the illustration that the two ends of the cylinder can be easily taken off, and the suction valves examined and repaired. By the double action of the pistons, which force the water alternately, a constant delivery is kept up. From the small amount of labour this pump entails, and from its durability, it will be found very applicable for domestic use.

By Fig. 106 is shown one of Warner's lift and force pumps for yards and offices.

FIG. 106.

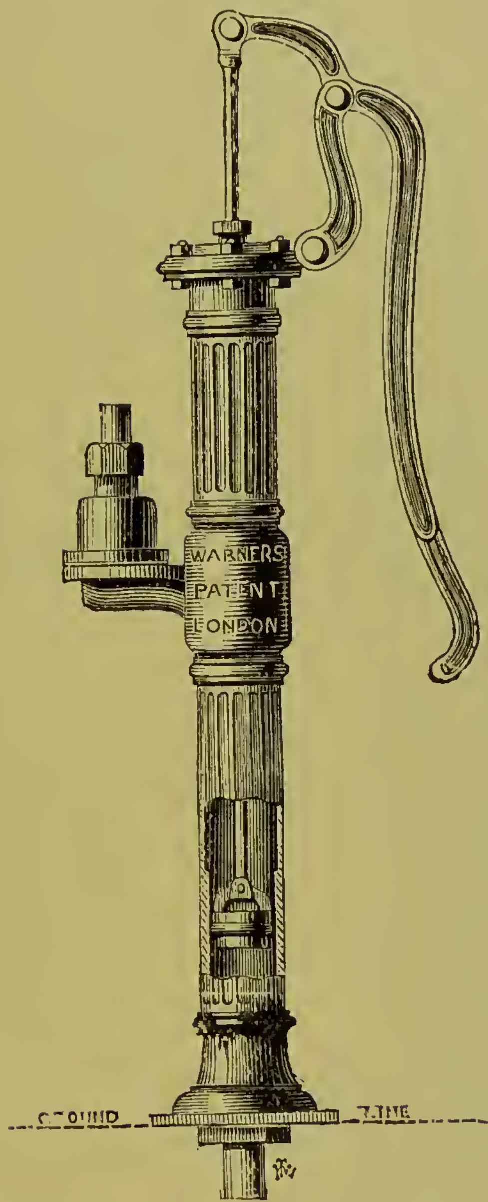
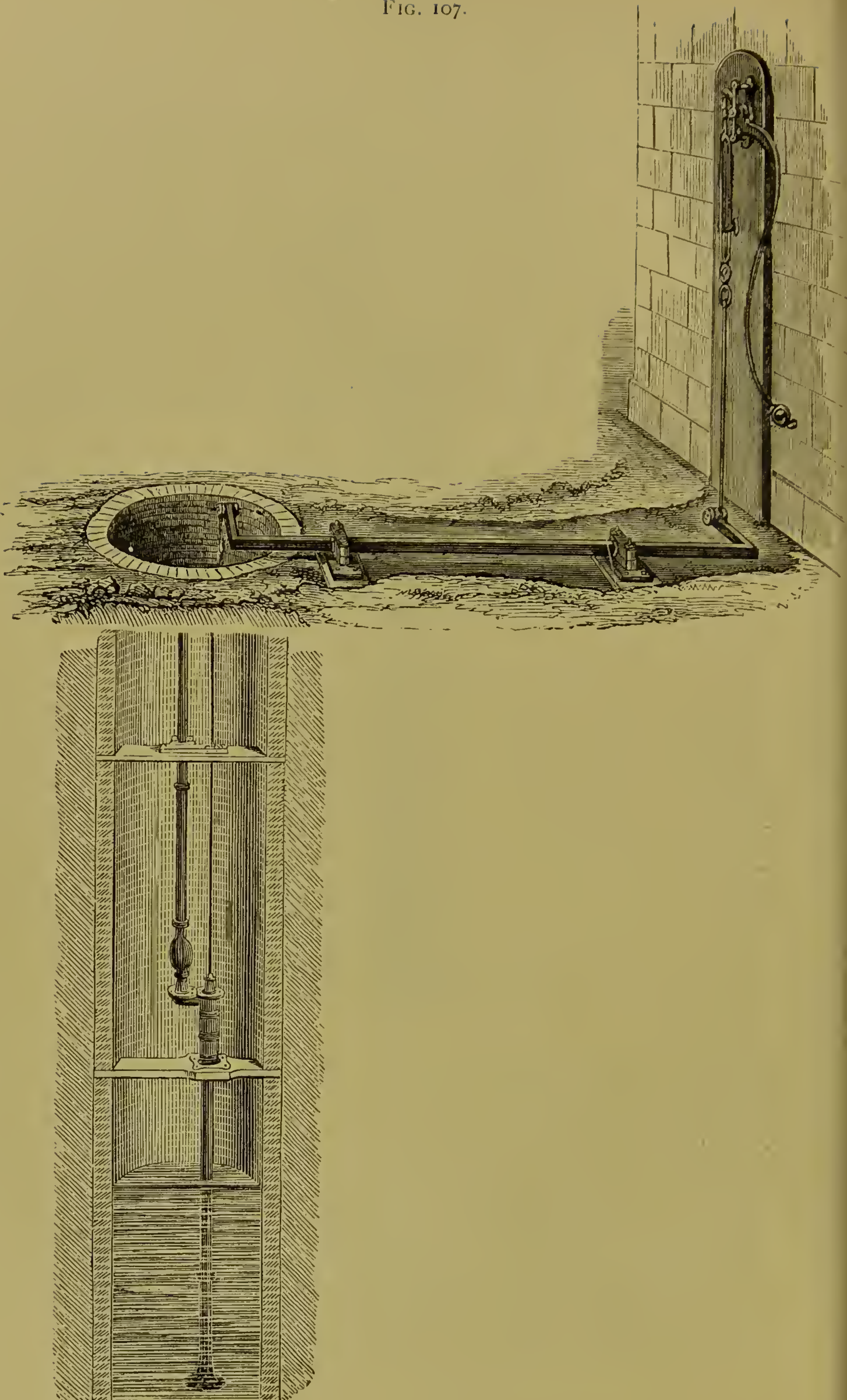



Fig. 107 shows how the lift and force pump, though still of a size suitable for hand-power, may be fixed and worked for the supply of water from deep wells. The barrel of the pump will generally be fixed near the surface of the water, the depth between the barrel and the water in the well representing the suction, and that above the forcing action of the pump. All other barrel pumps are modifications of the lift and force pumps in some way or other. They are arranged on a single or multiform principle by different arrangements of valves or pistons;—by double barrels (*see* Fig. 88, Section LXXI) or treble barrels (as illustrated by Fig. 89, Section LXXII, and Fig. 96, Section LXXV).

Fig. 107.



Front and side elevations of one of Warner's pumps with three barrels, or, as it is termed, a three-throw pump, are shown by Figs. 108 and 109.

FIG. 108.

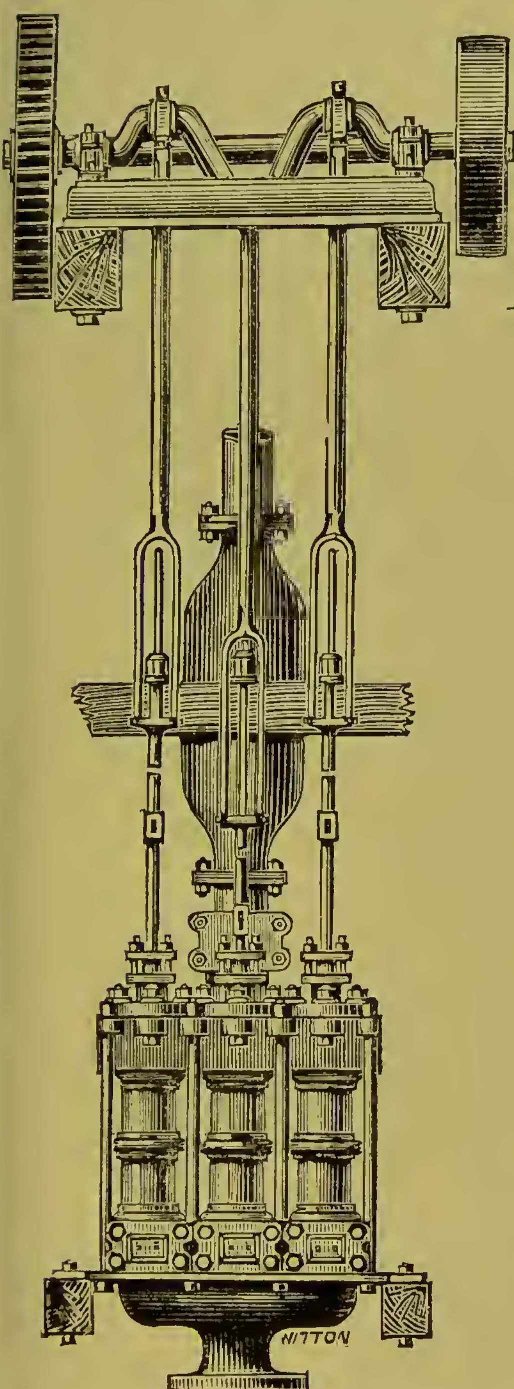
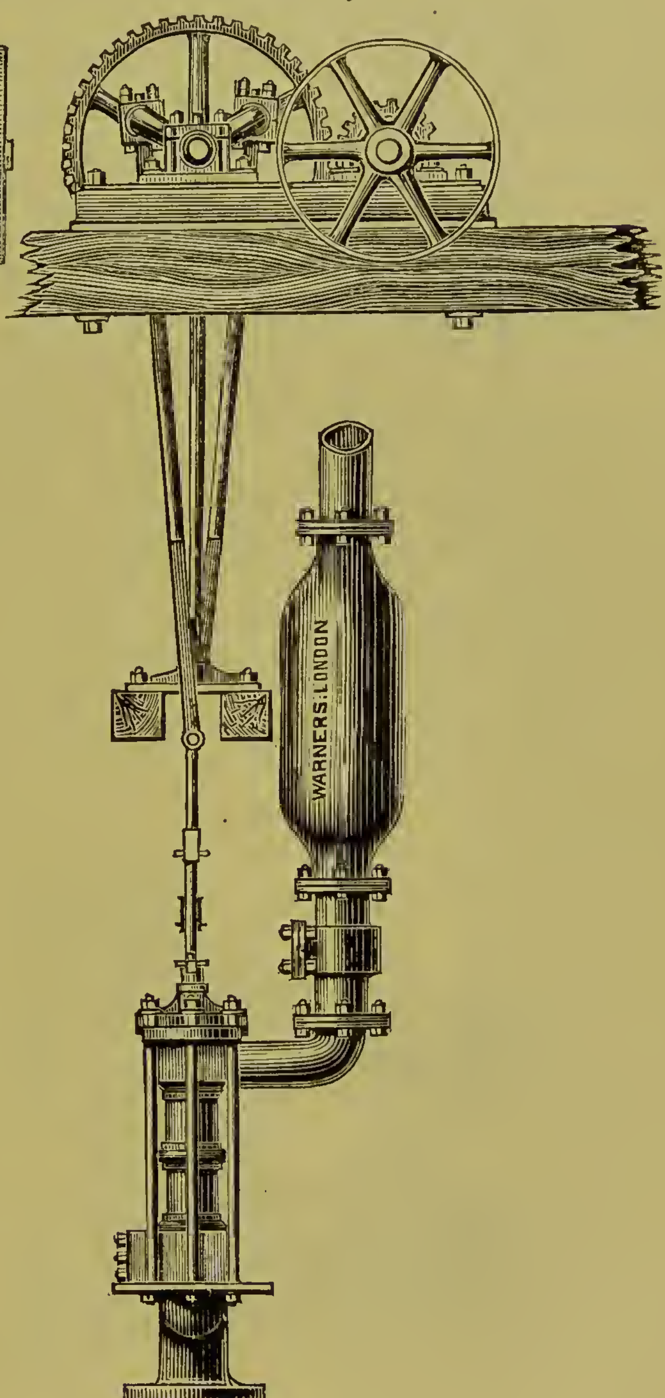


FIG. 109.




The different modifications give to pumps different names. They are sometimes called bucket pumps, ram and plunger pumps, and sometimes solid piston pumps.

A continuous stream is very effectually secured by pumps worked in sets of three, and in those known as plunger and bucket pumps, which act both in the up and down stroke.

In fixing force pumps in situations where the rising main is of any length, an air vessel should be provided, in order to relieve the pipe from strain, and to insure a continuous discharge of water (*see* the last illustration).

When hand-power is employed the single barrelled pump worked by levered handle, or the doubled barrelled pump worked by frame and crank, may be adopted, but with horse or steam power as the motor, the treble barrelled pump is to be preferred.

In shallow wells the internal diameter of the suction and force pipe should never be less than two-thirds of the internal diameter of the barrel of the pump, and in deep wells the suction and force pipe should each be of the same size as the barrel.

In all wells—especially in deep wells—it is desirable that the pump work should be fitted with great care and strength.

LXXX.—CENTRIFUGAL PUMP.—This pump is now coming more and more into use. Its name explains its action; it is very compact, and is easily connected to the ordinary rotative steam engine by a driving belt. These pumps are only applicable to lifts of 20 feet. The centrifugal pumps made by Messrs. Gwynne, and which have been previously referred to in this work, are shown by Figs. 110, 111, and 112.

FIG. 110.

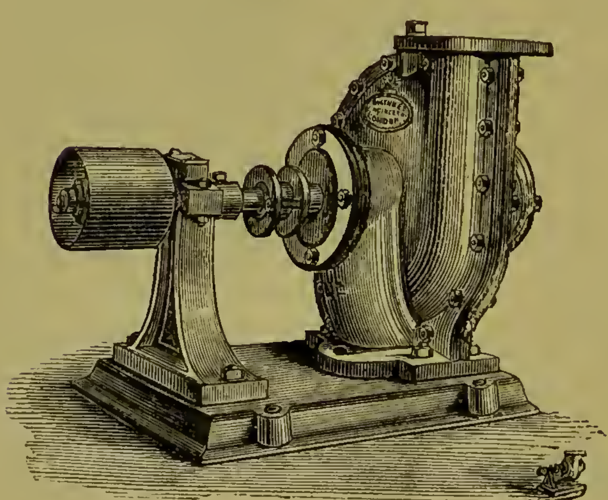


FIG. 111.

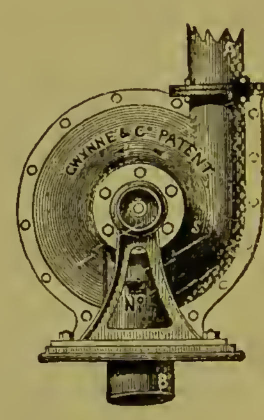
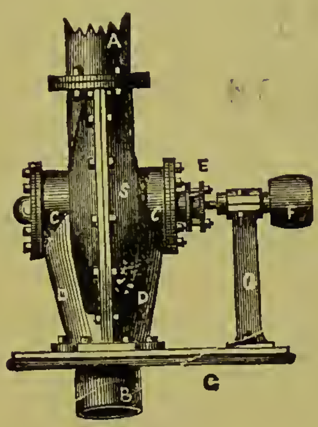



Fig. 110 is a perspective view, Fig. 111 is a side elevation, and Fig. 112 is an end elevation of the pump. In the last figure, S is the body or case; CC the side cylinders or water passages communicating with the revolving wheel or disc, and DD the

suction pipes on each side of the case, which unite together on or below the bed plate G, in one pipe B. This is considered an

FIG. 112.




important feature in the arrangement, as the machine is rendered extremely compact. In one of the cylinder covers or ends, there is a bearing supporting the spindle on which the wheel is fixed; in the other cylinder or cover there is a gland and a stuffing box E, through which the shaft of the revolving wheel passes. Q is a standard supporting the shaft. F is the pulley by which motion is communicated to the pump from any prime mover. A is the discharge pipe, which may be carried upwards to the required elevation. The suction pipe B may, if desired, be run any moderate length horizontally, and the pump may be placed 15 to 20 feet vertically above the water to be raised. A foot valve is placed at the bottom of the suction pipe.

The action of the pump may shortly be stated to be as follows :—The pump case and pipes being filled with water, the wheel or disc is caused to rotate, and by the centrifugal motion thus given to the water contained in the disc, it is driven out into the case or receiver of the pump. The partial vacuum thus formed in the disc is filled by the water forced up the suction pipe by the pressure of the atmosphere; in entering the disc, centrifugal motion is communicated to the water by the revolving disc, and thus a continuous stream is received into and discharged from the pump. To prevent the water from rotating in the case, and to give it a direction upwards to the discharge pipe, a stop or plate is placed at the base of the discharge pipe, reaching to the joint between the piston and the case. Another form in which the centrifugal pump is introduced is that of a horizontal fan fixed at the bottom of the pump well, and working on a vertical spindle. This form is suitable for higher lifts, and is hardly applicable to any class of dwelling.

LXXXI.—CHAIN-PUMPS: NORIAS.—In addition to the foregoing there are the pumps known as chain pumps, consisting of an endless chain having buckets, which revolve with the chain and discharge their contents on each revolution, attached at short intervals. These pumps are, however, hardly suitable for the raising of water for domestic use in dwellings. The same remark applies also to various other machines which are occasionally used for the raising of water under different conditions, some of them being of ancient origin, such as the old noria—which is not unlike the modern chain pump—or the screw or spiral pump, which may be used for special purposes. It should be added that when a well is completed, and the pumps and engine fixed, the care of the works is a matter of much more importance than owners generally suppose. Periodical visits to the pumps for the purpose of ascertaining their condition are necessary, and their parts must always be kept in proper working order. To do this iron ladders should be fixed to give access into the well.

## CONTENTS OF CHAPTER XI.

### STORAGE AND DOMESTIC FILTRATION.



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# CHAPTER XI.

LXXXII.—Underground Storage Tanks.—The storage of water in reservoirs or underground tanks for the supply of private dwellings is an object requiring much care and attention in details. If it is determined to collect surface waters it will be necessary to have proper and ample storage room to meet any droughts that may occur, and to associate with it proper filtering arrangements. A provision for the consumption of 120 days may be taken as a safe one, even in the driest parts of England.

The cost of making underground tanks which must be perfectly water-tight, so as not only to prevent the escape of that which is stored, but also to preserve the stored water from the influx of polluting "ground water," will vary extremely.

In certain situations, where the subsoil is of such a character as to allow of the space which the tanks are to occupy being cut out of the ground in the precise shape and size the proposed tanks are to be made—and this can be done in the chalk, and the new red sandstone formations with remarkable exactitude—it has been found necessary only to face the surfaces of the excavation with a rendering of cement to make them water-tight, and then to cover them with a roof of brickwork springing from shoulders of concrete or resting on iron girders. These have been constructed under favourable circumstances at the low cost of from 30*s*. to 40*s*. per 1,000 gallons.

The increasing experience which we are now gaining in the use of concrete, facilitates the construction of tanks in soils not naturally so favourable as those which I have just referred to, at a cost much less than formerly, if proper care is taken in the selection and mixing of the ingredients, and in the washing out of any earthy matter. Portland cement is found to be better than

the best lime, though concrete, consisting of one part of blue lias lime, and six parts of gravel and sand—or of the proportions which are favoured in France, consisting of two parts of broken stone to one of mortar, the latter being composed of three parts of lime to five of sand,—with an inside rendering of Portland cement and sand in equal proportions, will form a tank of unexceptional character. The thickness of concrete will depend upon the soil in which the tank is constructed. If it be of a slipping character the thickness must be increased.

In some cases it will be found desirable, instead of "rendering" the inside with cement only, to line the concrete with 4½-inch brickwork, laid in cement and well grouted with a parting or joint of the same material between the brickwork and the concrete.

Where the tanks are of large dimensions, it will be necessary to support the roof with brick piers and buttresses, and construct the roofs of brick or concrete. The cost of these tanks will vary from £5 to £7 per 1,000 gallons. A tank 16 feet by 12½ feet, and 8 feet deep, will hold more than sufficient to supply five persons with 15 gallons of water for 120 days, after allowing for evaporation, while a tank 16 feet square, and 12 feet deep will hold more than sufficient to supply 10 persons with 15 gallons for 120 days. In the one case the storage space will be 9,600 gallons, and in the other 19,200.

It may be useful to remember that a rectangular space 16 feet by 10 feet holds 1,000 gallons in every foot of depth and that a circular one 14¼ in diameter holds about the same number of gallons.

LXXXIII.—Cisterns for Service within the Dwelling.—It is very unsatisfactory to be obliged to acknowledge that after obtaining water of a potable character from river, spring, or well, or after conserving it in tanks, it may lose its good qualities in the service-cistern into which it may be raised for household supply; but this is found to be the case in very many instances.

We have now been led by chemical analysis to look upon water as perhaps the most dangerous substance upon which human beings have to depend for life and health; and, at the same time, to admit that, although we may obtain what is pure at its original source, and convey it in that condition to the dwelling, it may soon become defiled by the vapours, gases, and dust which pervade the atmosphere surrounding cisterns, or by the filthy condition of the cisterns themselves, or by the injurious character of the pipes by which the water is distributed for use. There is no doubt whatever that water is often most injuriously affected by foul cisterns and foul pipes. Nevertheless, there are but few exceptions in which isolated dwellings, beyond the reach of a public supply, can exist without cisterns, while there are many in which

the disgusting practice of placing them in or near attics which are used as sleeping apartments prevails. In fact, in many of the largest houses in the country this condition of things will be found, to be the case.

Cisterns should always be placed in separate but readily accessible places, well protected from frost and changes of temperature, by being encased in non-conducting substances, and never erected over any of the better rooms (a necessary precaution in case of accident). The waste or overflow should invariably be disconnected from the house sewer, or any of its branches. No cistern should be allowed to remain for twelve months without being thoroughly cleansed.

The best of all cisterns are those made of slate, enamelled inside, or of earthenware, and those that are constructed of wrought iron, properly painted. Lead and zinc for the linings of cisterns are both decidedly objectionable, though I believe that lead is often condemned, when the evil complained of is due rather to the effect of certain *impure* water upon lead than to any general effect of lead upon pure water. It appears to me exceedingly doubtful whether pure water has the effect so often imputed to it, of quickly oxidizing lead.

Captain Douglas Galton, in his work *Healthy Dwellings*, says on the subject of lead cisterns : "The action of water on lead appears to depend on the quantity of oxygen and carbonic acid. When there is a large quantity of oxygen, the lead is rapidly oxydized, and the oxide of lead is to a certain extent soluble in pure water; but if the water contains a sufficient quantity of carbonic acid to convert the oxide into carbonate of lead, which is only slightly soluble, the water will be comparatively safe from dangerous contamination. * * * * But in point of fact the conditions under which water acts on lead are so intricate, that it is preferable where any doubt exists to avoid such water for domestic purposes, if possible; or if no other supply is available to use iron or earthenware pipes for its conveyance, and slate or earthenware cisterns for its storage."

Where the whole of the water is raised to one service cistern in the upper part of the dwelling, special arrangements should be made as stated in Chapter V, for the supply of water-closets and sculleries by separate subordinate cisterns, so that the water required in either a water-closet or a scullery may be drawn without any *direct* communication with the main service cistern. To remove any defilements a filter should be connected with all service cisterns through which the *whole* supply of the dwelling should pass as required for use, for, the sideboard and table filters now so commonly seen, which only partially deal with the water consumed in dwellings, should be discontinued in favour of general house filtration, inasmuch as they are deceptive objects

which householders too frequently rely upon to correct the impurity acquired in cisterns.

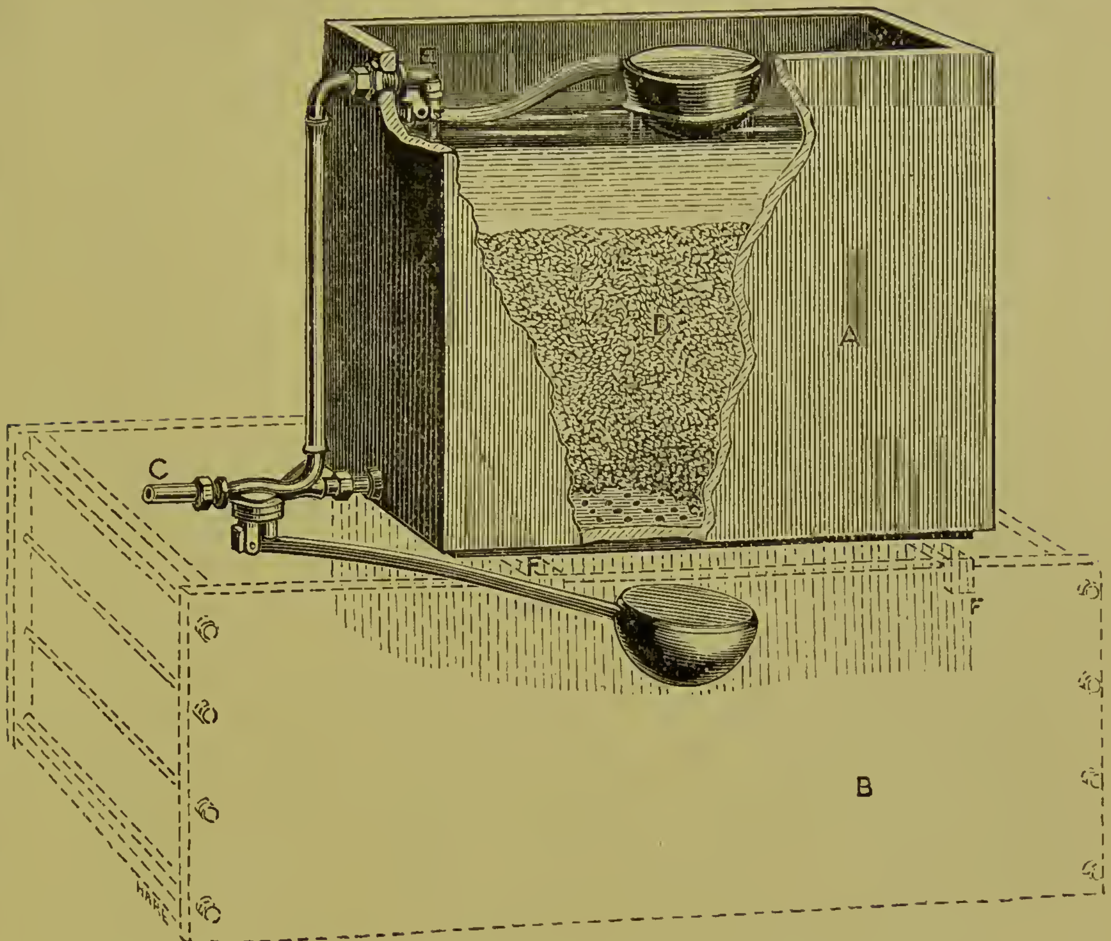
LXXXIV.—Domestic Filtration.—In any arrangement for the supply of water to dwellings domestic filtration should be included, although the Rivers Pollution Commissioners have stated—and in their statement I concur—that, as it is usually practised, it is of little or no use. They state, however, that if domestic filtration is properly performed it is much more efficient in purifying water polluted by organic matters than that practised on a large scale by the water companies—usually through sand—and I would add that where house filtration is carefully performed it is quite unnecessary to resort to the boiling of water as a means of correcting impurity.

Rain water collected from impervious surfaces, as shown in a previous chapter, is in itself so free from pollution that it requires filtration only to protect the consumer against the accidental defilements of smoke and other floating organic impurities which collect on such surfaces. It is in the house cisterns spoken of in the last section that water, whether rain or spring water, undergoes the defilement which filtration may successfully rectify. No water, which is radically impure, can be made chemically potable by filtration of any kind. Substances in suspension may of course be extracted by mechanical straining, whilst those in solution of an organic character may be oxidized by passing through aërated material, by which those matters are rendered imputrescible by contact with the oxygen of the air in the pores of the filtering material. The organic substances, in fact, as shown by Dr. Frankland, are burned with oxygen and decomposed, their nitrogen being turned into nitric acid, and their carbon into carbonic acid. Much more depends on the aëration of the material which should be kept perfectly clean than on the character of the material itself. Animal charcoal has been recommended in consequence of the very large surface it contains within itself, and which is due to its porosity; and where frequently renewed and intermittently aërated this material possesses the best qualities; when constantly under water its valuable properties are partially lost, and it becomes like other materials, a bed for rearing living organisms, which for the reasons already stated is not the case with the same material alternately wet and dry. Spongy iron must necessarily be under water to prevent that corrosion which would frustrate its special capabilities, which have been so highly commended by some chemists.

*Aërated Filters.*—It has been the pre-eminent purifying value of filtering material *intermittently aërated* that has led to the adoption of the Self-Supplying Oxidizing Aërating Filter, *see* Fig. 113.

This filter is made and sold by Doulton and Co., of Lambeth,

FIG. 113.




A. Filter.
B. Receiver of filtered water made to any size, in slate or other material.
C. Ball valve for supplying filter.
D. Filtering material.
E. Regulating valve for preventing the admission of water at a greater rate than it will filter.

in various sizes so as to serve for small as well as large establishments.* It should be placed below the service cistern in some accessible spot which will allow of the material being kept clean.

Its adoption possesses the following advantages. All water used for cooking as well as drinking can be passed through it, for, as will be readily understood by reference to the illustration, as filtered water is withdrawn from the lower storage receptacle, an equal quantity is admitted into the filtering vessel above from the general service cistern. By the perfect aëration of the filtering materials all organic matters absorbed by the water when in the house cistern become oxidized and rendered harmless. As the water

* Professor Corfield, having had his attention called to this filter, which was patented in 1876, states in his Lectures on Health in 1880, that "there is a filter, the construction of which is novel. It is called the *aërating* filter," though from the context of his remarks it would appear that he might be referring to some other invention unknown to the writer.

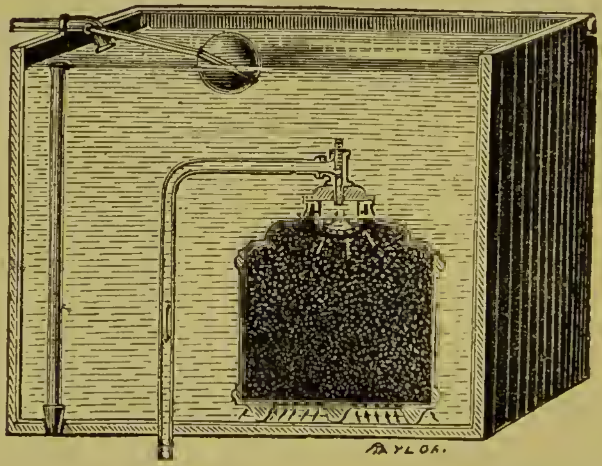
passes automatically through the filtering material, air follows it and takes its place. It is this alternate substitution of air for water, and water for air, that ensures purification. No neglect on the part of servants can prevent this automatic action.

The filtering material can be at any time readily cleansed, and, as there is no special patent for the material used, it is left to the purchaser to substitute any particular material that he may wish for in the place of that sent with the filter. For efficient filtration the material, of whatever kind it may be, should be cleansed or renewed at least twice a year. With doubtful water oftener.

This scheme of filtration (as in the case with any other which derives its supply from a storage tank) may be prefaced by another filter which is placed in the underground storage tank itself, and appended to the bottom of the suction pipe of the house pump. This filter, which was invented and termed the "Nosebag Filter" by the author, extracts from the water before it is lifted any solid matter which may be in suspension, and effectually *clarifies* the supply. The filtering material used under general circumstances may be sand and potsherds,—the latter coarser material being placed at the bottom, so as to prevent the finer from being drawn up through the suction pipe. This filter should be cleansed out once a year at least. Many of the small kinds of table filters now in use are stated by the trade to possess the benefits resulting from aëration, but inasmuch as they are not automatically supplied, perfect and systematic aëration is impossible.

*Non-Aërated Filters.*—These filters have necessarily their filtering material constantly under the water, and amongst the first of them should be noticed the "Danchell Cistern Filter," as shown by Fig. 114.

FIG. 114.



Its object and use are nearly the same as the Nosebag Filter just described, the difference being that the latter is used in the underground tank, while the former is placed in the service

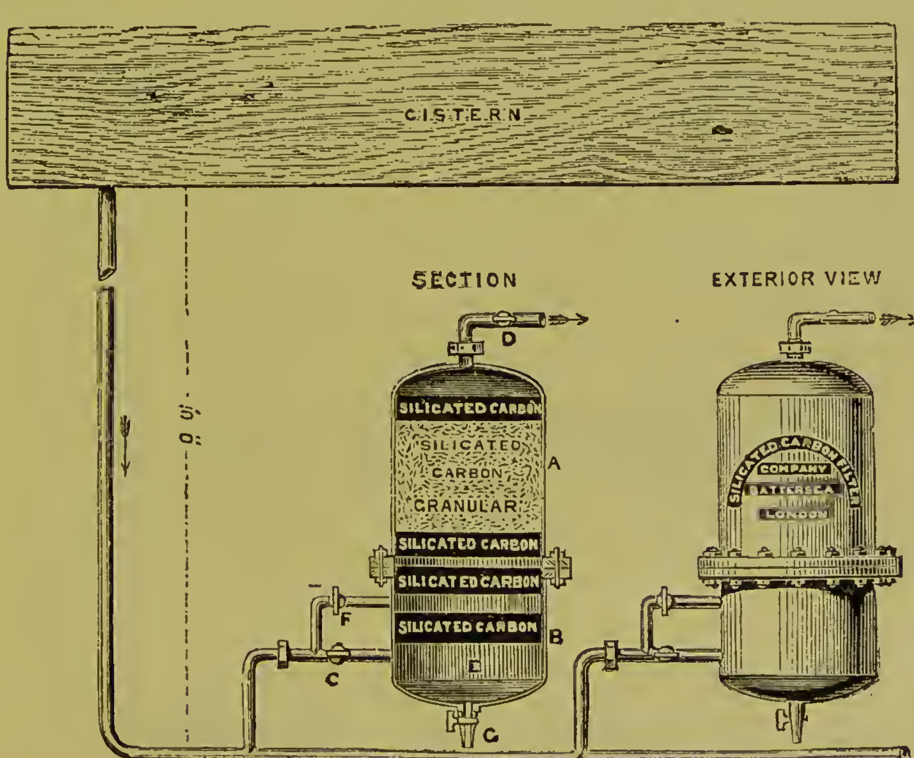
cistern itself within the dwelling. The material employed to perfect purification is animal charcoal, the vessel containing it being so arranged that the water passes from the bottom upwards and is drawn off from the top. The following analysis in parts per 100,000 has been supplied by the London and General Water Purifying Company, who own the patent and sell the filter :—

| Sample of water analysed. | Total solid impurities. | Organic Carbon. | Organic Nitrogen. | Ammonia. |
|---|---|---|---|---|
| Water before filtration ... ... | 30·90 | ·104 | ·001 | ·015 |
| Water after filtration ... ... | 15·35 | ·07 | Nil. | ·003 |

The two opposite kinds of filters, the Self-Supplying Oxidizing Filter and Danchell's Cistern Filter, should serve to broadly classify domestic filtration, which must necessarily have an aërated or non-aërated material for its purpose.

Among the first of the numerous filters in existence claiming special qualities, the silicated carbon, main supply, filter (*see* Figs. 115 and 116), should be noticed, Professor Wanklyn having declared that it will render river water containing a considerable amount of free and albumenoid ammonia as pure as deep spring water.

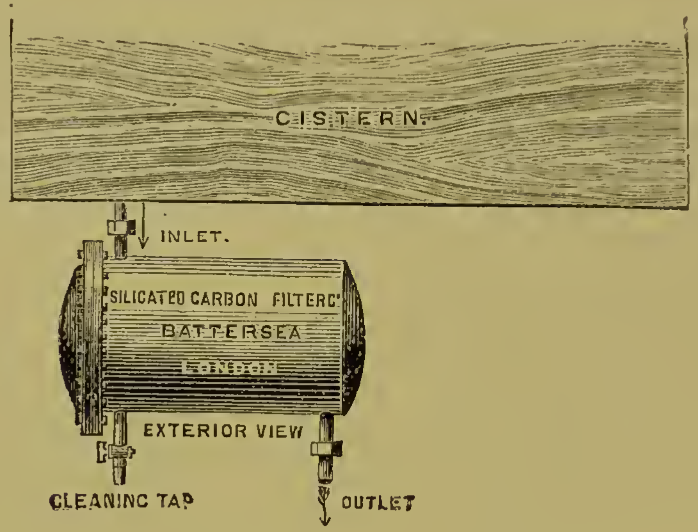
FIG. 115.



This filter is constructed in the form of a cylinder of stout copper lined with tin, the interior being fitted with slabs or plates of silicated carbon cemented into it, and the spaces between the slabs being filled with the same material in a granular form.

The filter can be attached either to the service pipe after it has left the cistern (*see* Fig. 115) or to the cistern itself as shown by Fig. 116.

FIG. 116.




In either case it is declared to effect the perfect filtration of the whole water supply of a dwelling, and thus aims at the same effect without aëration, as is undoubtedly gained by intermittent aëration. The cleansing of this filter is effected by simply closing the outlet and allowing the water to pass freely through the cleansing tap. This mode of filtration is said not only to remove organic impurities, but to render lead poisoning by water impossible, because, the makers state, "it alters the chemical character of any salt of lead which may exist in water and produces a compound which is insoluble."

A filter of Messrs. Atkins is shown by Figs. 117 and 118.

FIG. 117.

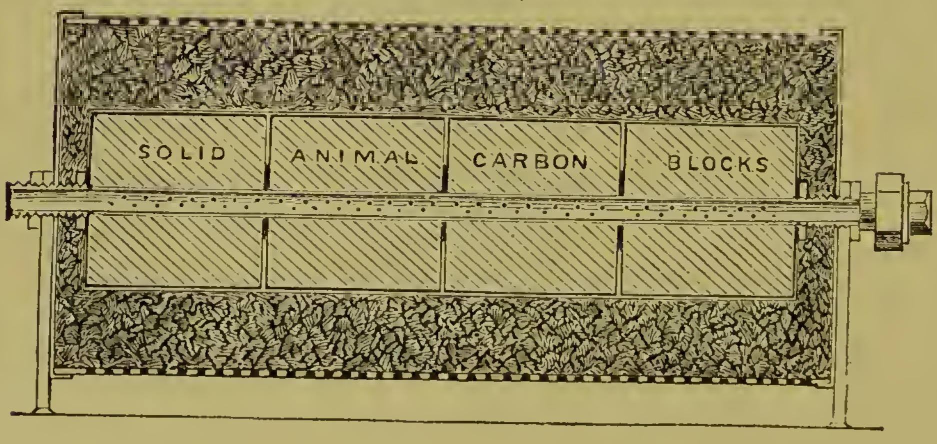
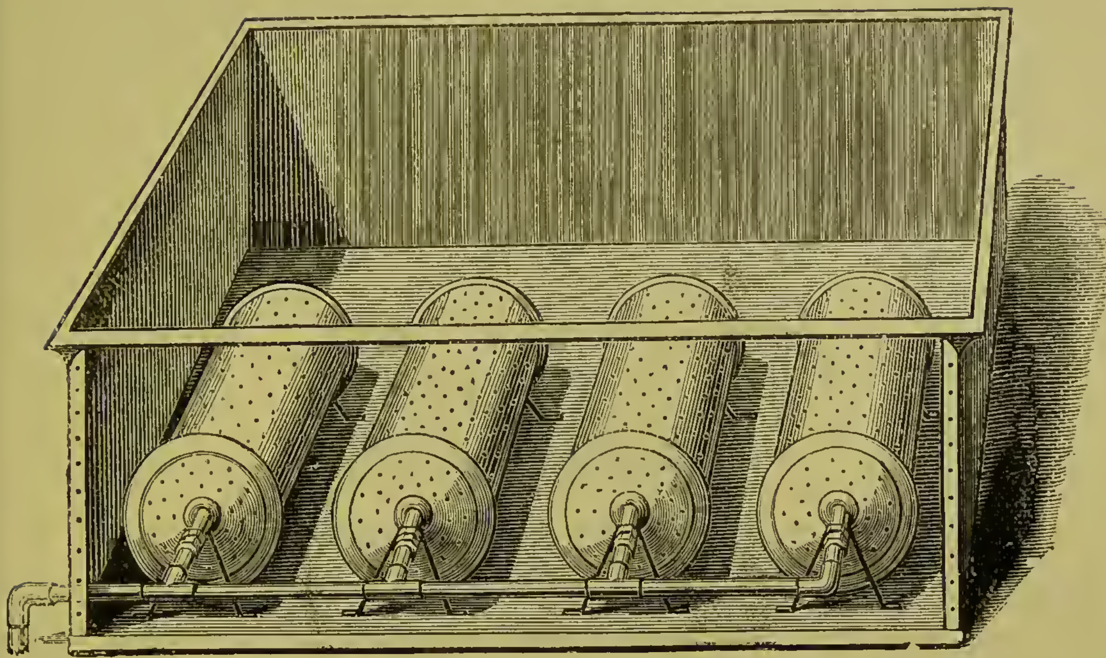


FIG. 118.



The filtration is effected through animal charcoal, in a block form, (*see* Fig. 117) placed in cisterns as shown in Fig. 118. The size of cistern and number of cylinders are governed by the quantity of water to be used in the dwelling. They may be increased as found necessary. Through the centre of each cylinder and block of carbon is a tube by which the filtered water passes out for use.

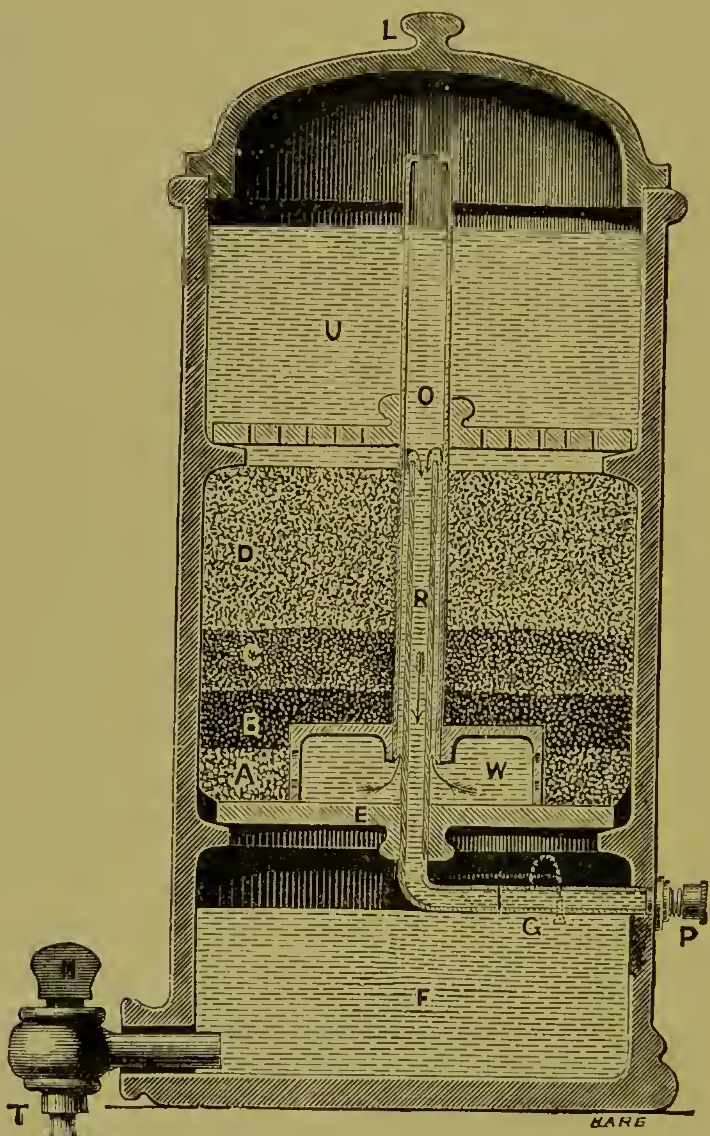
The next illustration to be given is the "Spongy Iron Filter," as shown by Fig. 119. The filtering material used in this filter is that from which its name is taken—spongy (metallic) iron, which has been reduced from an oxide without fusion, and which is therefore in a spongy, porous condition, of extremely fine divisions, weighing about 100 to 110 lbs. per cubic foot. The following example (taken from the Weekly Report of the Registrar-General) of the efficiency of this filter has been given me by the company who now possess the patent and supply the filter to purchasers. The figures given represent the constituents of the water in parts per 100,000.

| Sample of water analysed. | Total solid impurities. | Organic Carbon. | Organic Nitrogen. | Ammonia. |
|---|---|---|---|---|
| Water before filtration ... | 32·46 | ·139 | ·041 | ·002 |
| Water after filtration ... ... | 19·84 | ·028 | ·013 | ·130 |

Maignen's "Filtre Rapide" is another specimen of filter which is finding favour with the public. In this filter, the casing of

which is either earthenware in the small or block tin in the larger sizes, the filtering material used is animal charcoal reduced to an impalpable powder, purified and made to contain in its pores a proportion of pure lime. This combination is said to be most effective in purifying water and destroying organic matter. It is deposited in a thin layer over a filtering cloth of asbestos which is tied on a frame and inserted in the case.

Fig. 119.




U. Unfiltered Water.
D. Spongy Iron.
A, B, C. Prepared Sand
G. Regulator Opening.
F. Filtered Water.
T. Stop Cock.

In its small size this filter is very useful, for no more water need be put into it than is required for use at one time, and thus aëration of the filtering material may be secured. It is also easy with this small size to clean the asbestos cloth, and re-supply the charcoal.

The filter made and sold by Lipscomb, of the Strand, has been for a long time in use. It is, however, subject to the same drawbacks as other table filters—that it is left in the hands of domestics to keep replenished. In addition, the filtering material of this filter is cemented down, thus rendering inspection and necessary cleansing a matter of impossibility. In conclusion, it may be said of domestic filtration that periodical inspection and frequent cleansing of the material used is a *sine quâ non;* or the filtering material may, by the retention of polluting matter, actually communicate defilement instead of remove it.

## CONTENTS OF CHAPTER XII.

### DISTRIBUTION.



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# CHAPTER XII.

LXXXV.—Remarks on Constant Service for Dwellings in Towns.—It is now generally conceded from a sanitary point of view that the delivery of water from a public supply by constant service at high pressure is an object which should be aimed at where practicable. By the term "constant service," I do not mean a supply which is so curtailed by pea or pin ferrule as to be a mere dribble; but a sufficient delivery of water for all purposes and at all times to meet every reasonable requirement immediately it arises, the water being drawn direct from the main without the interposition of any service cistern or storage tank, which, as already said, is more frequently than anything else the cause of pollution in domestic water supply.

So general is the concurrence expressed by all persons unconnected with water companies in the advantages of avoiding house cisterns, that it is scarcely necessary to refer to the opinions of any one, however high he may be as a sanitary authority, in support of the same view. I will, however, give a few sentences from evidence given by Mr. Simon. He said: "I consider the system of intermittent water supply to be radically bad, not only because it is a system of stint in what ought to be lavishly bestowed, but also because of the necessity which it creates that large and extensive receptacles should be provided, and because of the liability to contamination incurred by water which has to be retained often during a considerable period." . . . . . . "The long retention of water in leaden cisterns impairs its fitness for drinking." . . . . "On the extreme inconvenience which

attends the storage of water in the poorer habitations of the city I have already reported to you, and will now only add that increased experience has given much confirmation to my view. These receptacles are generally such as contribute to the contamination of water, and are constantly so arranged as to invite an admixture of the most varied impurities." . . . . "The butt or cistern of the house, that on which the inmates depend for their supply of fresh and pure drinking water, is placed in immediate contiguity to the privy, so as to reduce the requisite length of connecting-pipe to the fewest possible number of inches; the application of water is not made discretionary on the users of the privy, nor are any of the cheap and common self-acting contrivances introduced; but the waste-pipe of the butt or cistern is conducted into the discharge-pipe of the privy, so that periodically, with a frequency varying according to the arrangements of the water company, the arrears of excrement are removed so far as the overflow of the water receptacle may have power to dislodge and propel them." . . . . "Water, as you probably know, is a very active absorbent of many gaseous materials."

The Rivers Pollution Commissioners in their report dated 30th June, 1874, state: "All storage of drinking water in houses is attended with the risk of pollution. Good water is spoiled, and bad water rendered worse by the intermittent system of supply. All drinking water ought to be drawn direct from the main. Under proper supervision the waste of water is less on the constant than it is on the intermittent system of supply. These and other advantages have led to the adoption of the constant system is a great majority of British towns."

The argument used against a constant supply is, that it encourages, and in practice results in, extravagance on the part of the consumer, and that no provision which can be made by any sanitary authority or private water company, however great, can be maintained with economy where such latitude exists. The answer to this is, that neither extravagance nor waste need be experienced under proper management and the use of proper appliances. This is, to a great extent, proved by the fact that in certain towns where a constant supply is now in use with the advantage of proper precautions to prevent waste, the quantity consumed is not more than from 14 to 16 gallons per person per diem.

LXXXVI.—STOP-COCKS.—Stop-cocks are generally placed on the branch service pipe communicating with the dwelling between the point of junction with the main and the premises supplied, as a means cutting off the entire supply when necessary for the repair of fittings or otherwise.

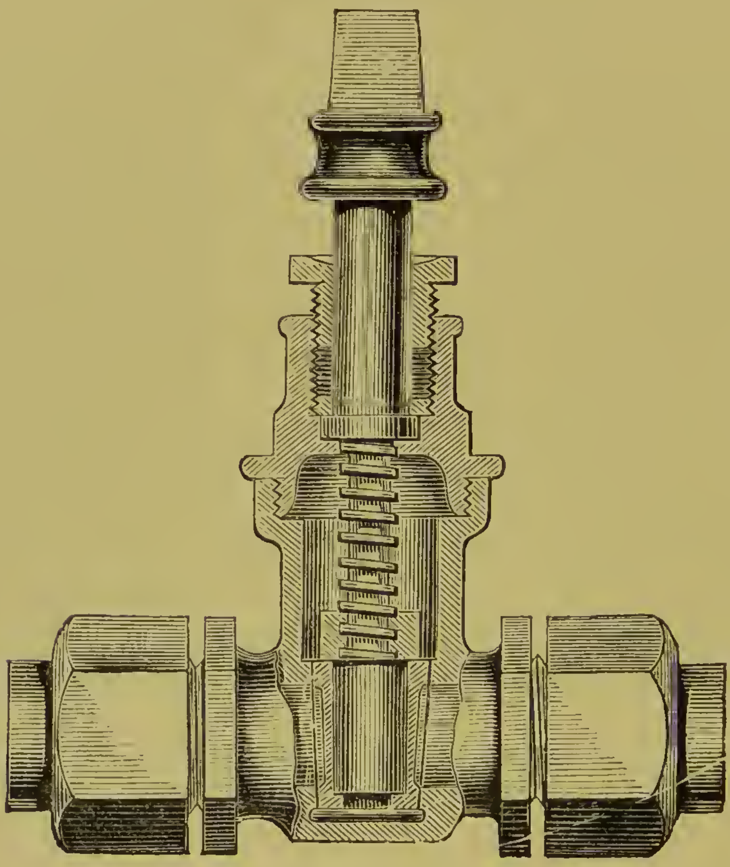
The old form of plug-cock is seldom now adopted—the screw

down loose valve stop-cock or stop valve cock being generally used as more durable, as avoiding the concussion caused by the closing of the plug-cock and as more certain to prevent the passage of foul air into the mains when the branch pipes are emptied. It is also desirable in the case of intermittent supply to provide a stop-cock for every pipe leading from a cistern, so that repairs may be executed along any particular line of pipe, without it being necessary to empty the cistern or to interfere with other lines of the service.

Numerous are the points, too, where stop-cocks are essential to the economy of supply throughout a dwelling, and it is needless to say that a stop-cock fails in its purpose that leaks in any degree.

Fig. 120 illustrates a stop valve cock made by Messrs. Stone, of Deptford.

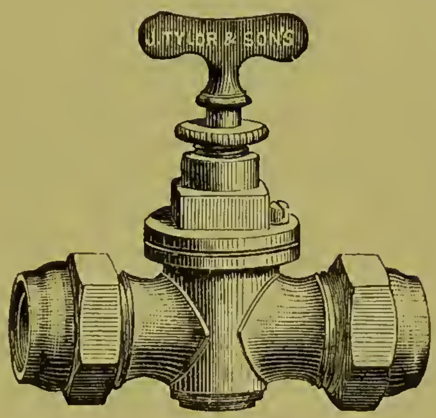
Fig. 120.



This stop-cock, which is turned by means of a key, is a good example of what should be always aimed at, as it affords when open a clear unobstructed passage for the water right through it, equal to the full bore of the pipe. When closed it is throughly secure against leakage, having two tight surfaces, each of which

acts as a perfect valve. Its construction also is very simple. Fig. 121 illustrates a smaller stop-cock, by Tylor and Sons, to be turned with the hand, which will be found very useful for branch service pipes. It is suitable for high pressures as well as low.

FIG. 121.

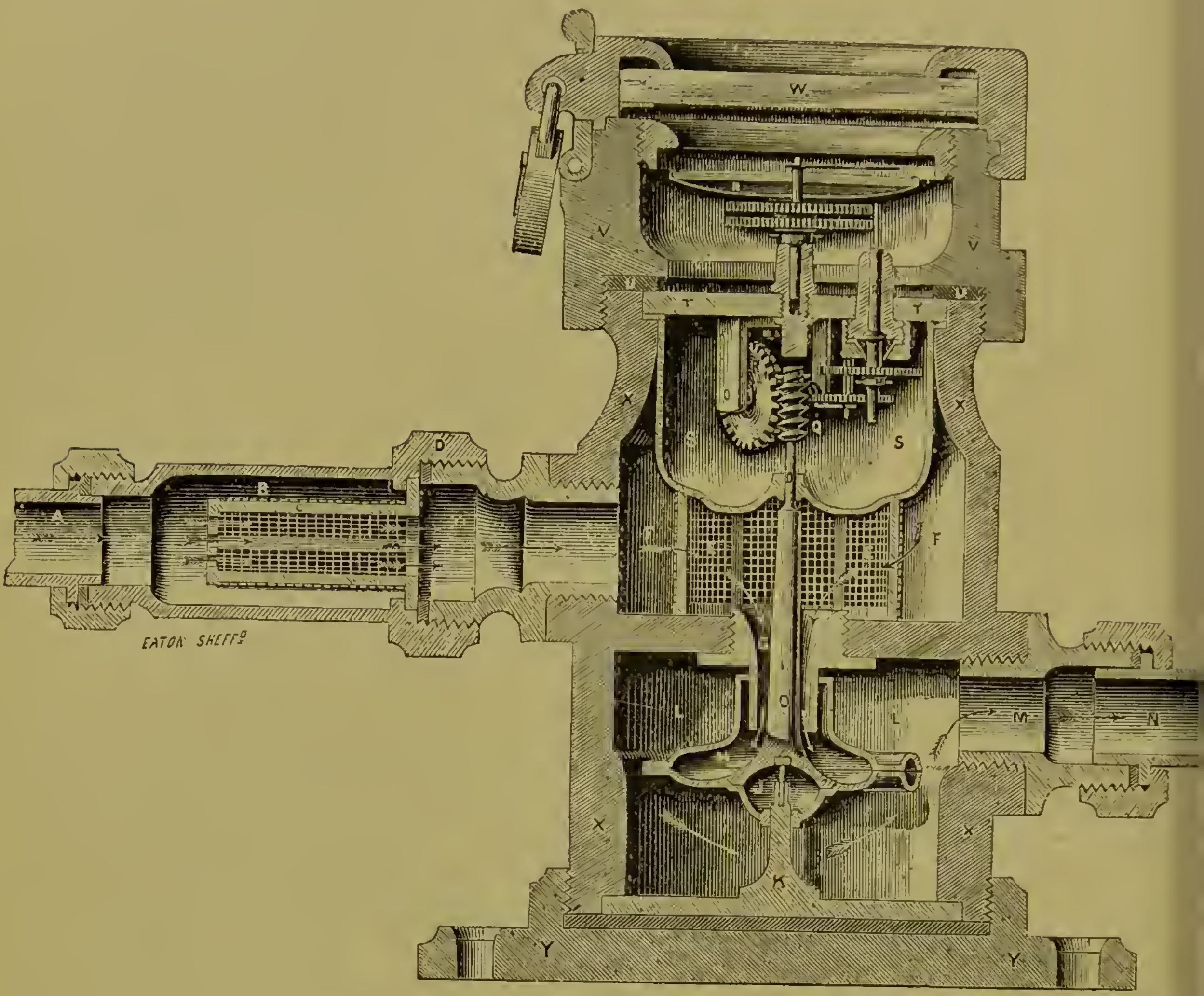



LXXXVII.—WATER METERS.—A certain means of preventing waste is the use of a private meter in each house, in the same way that meters are now adopted for the measure of gas in nearly every dwelling where gas is consumed. There is this difference, however, between water and gas; the use of a certain quantity of the first is an essential in life, while with the other it is not. If water were paid for upon the exact quantity consumed, it is believed that a very large number of the population would reduce their consumption to a minimum that would be prejudicial to health, and result in an evil much greater than the waste of water. The idea of charging by meterage for every drop of water used in a house has therefore been abandoned, but it does not follow that the system in a modified form should not become general at no very distant date.

In applying the meter system to separate houses, it has been proposed that a certain quantity of water should be considered due to each house according to its size and its rateable value, and that the payment for that quantity should be unchangeable even though the water should not be wholly used. Beyond this certain amount the customer should have power to draw from the main any greater quantity that may be required. For this *extra quantity*—it is held—an extra payment should be made. The meter would indicate the total quantity of water consumed, and so furnish the means of ascertaining the excess to be paid for in addition to the fixed quantity. By this plan no encouragement would be given to a niggardly use of water, and the company supplying the water would thus have guaranteed to it a certain minimum income.

Fig. 122 shows in section a half-inch water meter constructed by Guest and Chrimes, of Rotherham, upon Siemens and Adamson's patent.

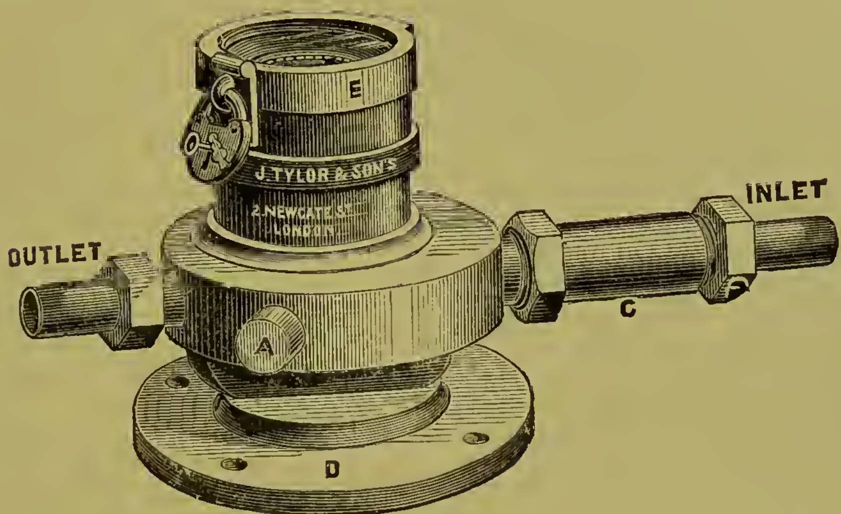
FIG. 122.




This meter, which is shown on a large scale to illustrate its component parts, is constructed upon the principle of the Barker's mill. The measuring medium consists of a drum, working on an upright spindle at the bottom, and in a collar at the top. The water is conveyed by the conducting tube into the centre of the drum, and allowed to escape at three or more apertures on the periphery of the same, giving to it a rotary motion. At each revolution of the drum a certain number of cubic inches of water is delivered, so that it is only necessary to register the number of revolutions to ascertain the quantity; this is effected by wheels and pinions, and the result indicated in gallons or feet upon a graduated dial.

Fig. 123 represents the exterior of a water meter occupying, as will be noticed, but little space, made by Tylor, which is well adapted to the registering of small quantities, and is very compact in itself. The figure will serve to show the compact character ot the instrument. This meter is so arranged that any repair or adjustment may be easily effected without removal. The small meters of this class are made of brass and gun-metal to avoid corrosion.

FIG. 123.




LXXXVIII.—HOUSE SERVICE PIPES.—House service pipes, the small pipes by which the water is conveyed from the street main or the house supply cistern into and about the dwelling of the consumer, are made of either lead, cast or wrought iron, lead alloyed or lead lined inside with tin. They have also been made of iron with glass lining, of enamelled iron, and in some few cases of brass, copper, and gutta percha, though these latter sorts have never been extensively adopted.

A great deal of prejudice exists against the use of lead, from the belief that water, especially soft water, acts in such a manner upon lead as to produce a poisoning effect, and a great deal of medical and scientific evidence has been brought to bear in proof of the assertion. The result of long enquiry tends to prove that, though certain kinds of water—particularly very soft water—will under certain conditions be injuriously affected by lead, with other kinds of water under different conditions no such effect is produced, and that there are generally found in water impurities which will after a time neutralize the effect of corrosive action and deprive the water of the power of producing any injurious effect. Glasgow, for instance, which, as is well known, derives its water in almost as pure condition as it can be found, from Loch Katrine, is provided with lead pipes for all house service, and the case is the same at Manchester. It may be taken for granted,

that in short lengths of pipes where water is in constant use, lead may be used without any danger, whereas in long lengths of pipes, in which water is liable to stand for any length of time, or in pipes which may be for some time empty, lead should be avoided. Lead pipes, in fact, should never be allowed to stand empty for any length of time.

Wrought iron is a general substitute for lead. The great objection to wrought iron is its liability to rust, by which means pipes may become choked up in a few years. This is especially the case with soft waters. Another objection to its adoption is its non-pliability. This may be minimized by the insertion of double screwed joints which may afterwards become of great assistance should the pipe become at any time choked up. Galvanized iron is said to be no protection against rust, and in many cases the iron unequally and imperfectly coated with zinc has been more rapidly corroded and destroyed than if it had never been protected at all. As a substitute for wrought iron and lead pipes iron or lead pipes with a continuous lining of tin of even thickness have proved very useful. When they are adopted, Mr. Parry says in his work, "*Water, its Composition, Collection, and Distribution*," care must be taken that the tin is without flaw within the lead, and that the outer casing of lead is of sufficient thickness to resist the maximum internal pressure which the pipe will have to bear independently of the tin lining, and also that the tin is of uniform thickness throughout the pipe.

One of the best safeguards against rust is the enamelled iron previously mentioned. This material has been used with success where all other kinds have failed. Care, however, is required in the jointing, as the enamel cannot be continued over the screw joints.

In England all pipes laid out of doors should be laid at a depth of at least 3 feet below the surface—and if from necessity this cannot be done and they are placed in an exposed condition, the pipes should be covered with sawdust or some other non-conducting material, and if passing through bad ground should be cased in timber. Within dwellings pipes should never be bedded in the plaster work of walls, for this system causes a vast amount of injury, but they should be always placed in an accessible position, either exposed altogether and painted, or cased in wood work which should be made to open readily. If from necessity they have to be laid against an external wall, they should be fixed to wood work and not placed in direct contact with the wall itself. In all dwellings it is a matter of the greatest importance that the service pipes should be capable of being drained dry. This precaution will prove of great value in very cold weather. To prevent freezing with more certainty it will sometimes be advantageous to light a small gas jet and apply it to the water

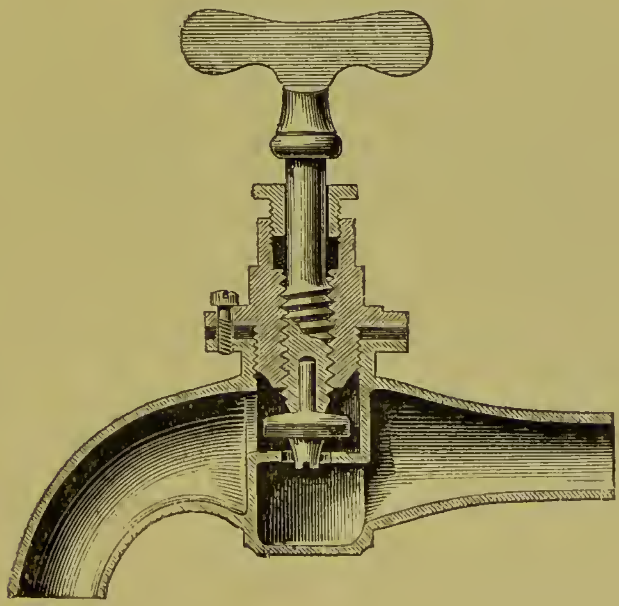
pipes where they enter the dwelling. The quickest method to thaw pipes is to pour hot water over them or to place cloths dipped in hot water over the spots where the stoppage is supposed to exist.

LXXXIX.—TAPS.—Taps being the outlets from the house service pipes from which the water supply of the dwelling is drawn, have naturally a most important bearing on the economy of domestic water supply. They may be classified as follows :—(1) plug taps; (2) screw-down taps; (3) self-closing taps with various modifications; and (4) self-closing screw taps; but they differ so much in detail that all persons interested are advised to examine the catalogues of the various manufacturers and agents before making a selection.

(1.) *Plug Taps.*—The ordinary plug tap which is familiar to every one, may still be said to answer its purpose when the water service is intermittent, and is distributed through the medium of cisterns. Where, however, the supply is delivered at high pressure on the constant system, such a tap becomes unsuitable, as it allows the water to be shut off so suddenly as to cause a severe concussive bursting strain upon the pipes, and when the tap is only partially closed the pressure of water behind it may at times be, and often is, sufficient to force it open and cause waste. To meet these objections screw-down taps, self-closing taps, and self-closing screw taps, have been to a great extent adopted.

(2.) *Screw-down Taps.*—Screw-down taps have the merit, as their name implies, of closing gradually, and thereby *not* producing any concussive strain upon the pipe. They are capable of being made very durable and when out of order can be easily repaired.

FIG. 124.



It is always necessary when they are adopted, in order to prevent waste, that they should be perfectly screwed down. This is not always done by servants, or if done is done so carelessly as to act injuriously upon the seating, thereby rendering the tap leaky.

Fig. 124 represents one of Guest and Chrimes' high pressure screw-down taps. The valve of this tap is a loose valve, and is closed, as will be seen by the illustration, by being pressed upon a metal seat by means of a screw-plug.

Figs. 125 and 126 show in section and elevation Tylor's gun-metal high pressure screw-down tap. The valve is, as will be noticed, constructed on the same principle as the sluice valve so

FIG. 125.

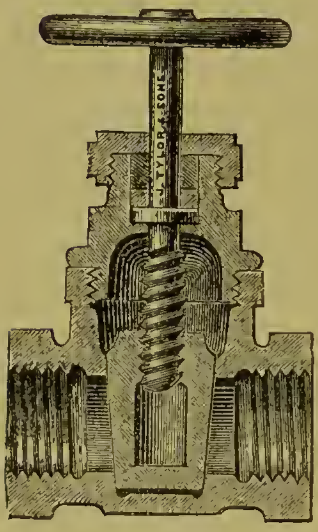
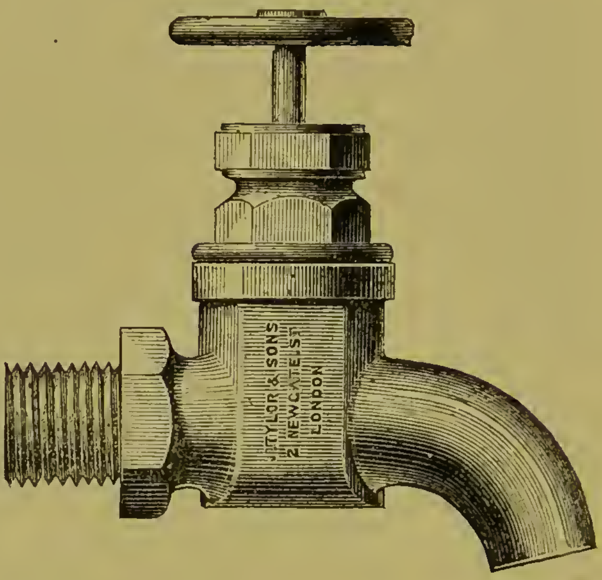


FIG. 126.

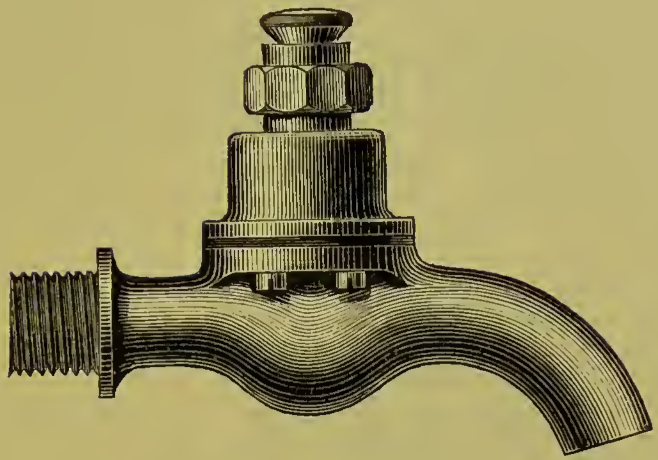



well known to engineers. It has a full way and from its strength is capable of resisting very high pressures.

(3.) *Self-closing Taps, &c., &c.*—Self-closing taps are largely adopted in dwellings, because they effectually prevent waste, and do not entail so much trouble in opening and closing. They have, however, the same defect as plug taps, inasmuch as they arrest the water too suddenly, and in addition they are liable to derangement from the carelessness of servants. They should therefore only be used in places where the occupier can see that they do not suffer rough treatment.

Fig. 127 shows one of Doulton's taps suitable for high pressure. The valve is shown as closed. To open it the knob must be pressed; this opens a valve inside the cover relieving the pressure of water which is collected on the upper side of a loose piston, the consequence being that the whole pressure of water is exerted on the underside of the piston and drives it up thus

Fig. 127.



allowing free passage through the outlet port. On releasing the knob the relief valve returns to its closed position and the water passes through the annular space around the piston and collects on the top of it and gradually forces it down on to its seating, the area of the top of piston being greater than the bottom of same. Thus the greater the head of water the tighter the valve becomes when closed.

Fig. 128.

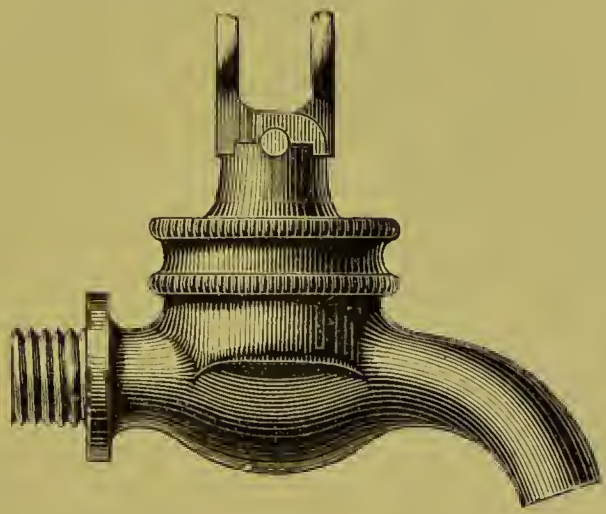
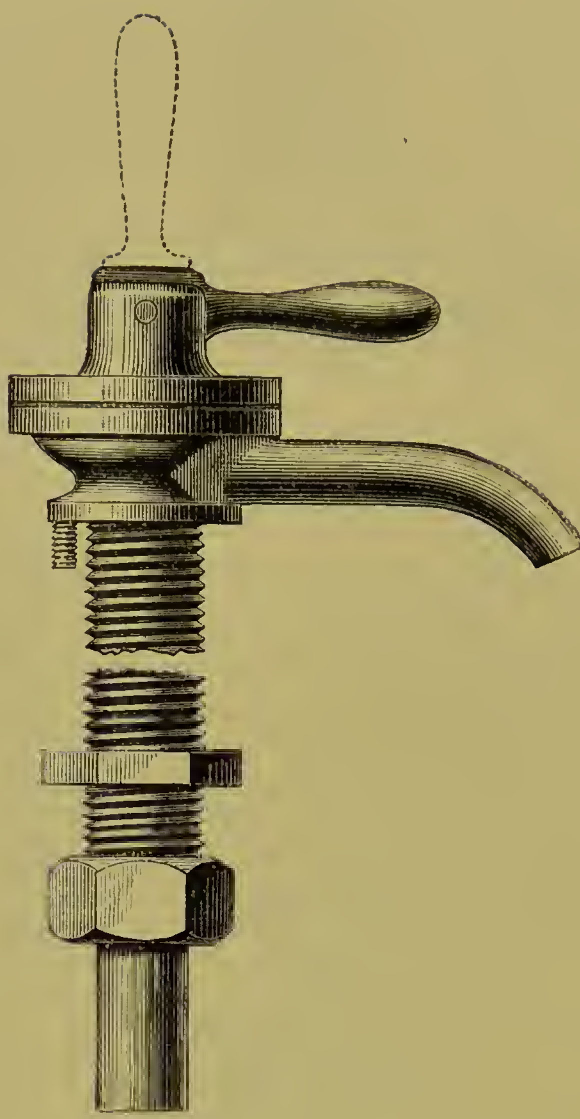


Fig. 128 shows a tap by the same makers more adapted for low pressures; the difference being that the relief valve is dispensed with and a spindle attached to the piston; to the latter double cams are connected, and by closing these the piston is pulled off its seating and returns again on being released. The pressure, as in the previous example, gathers on the top and keeps the valve tight.

An ingenious sort of tap is shown by Fig. 129.

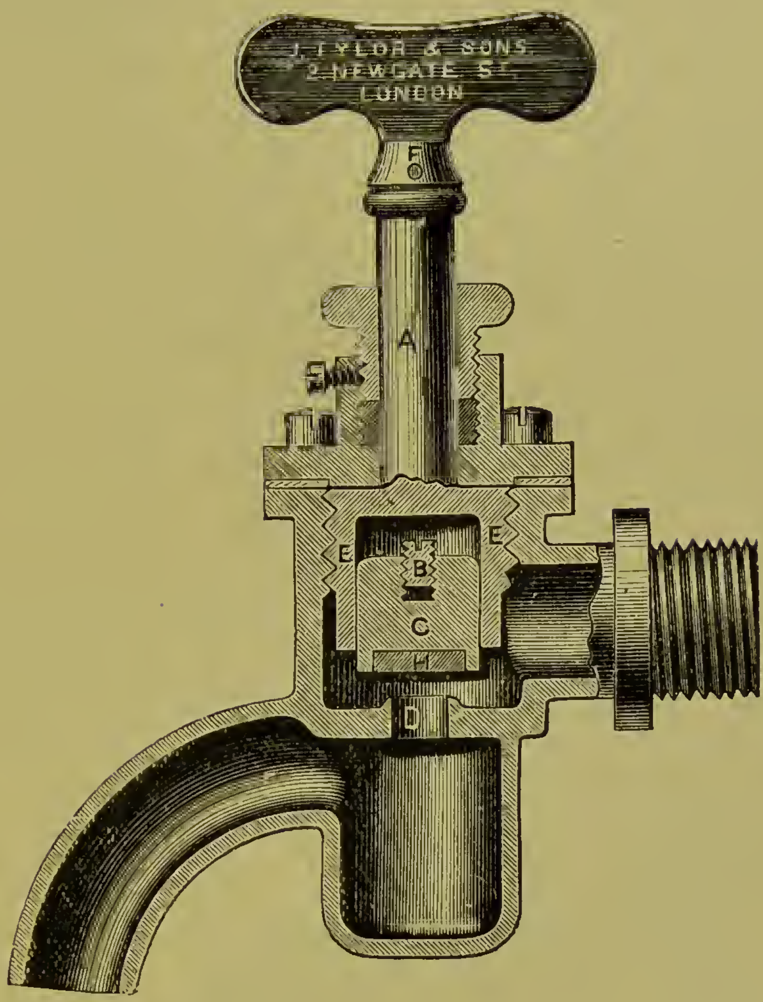
FIG. 129.



Here the cam lever is so arranged that on raising the same it will immediately fly up to the vertical position shown. The valve cannot therefore be left partially open, though it may be *held* in such a position as to allow a small quantity of water to be drawn off. This tap is made by Doulton and Co., who also have recently brought out another lever tap with india-rubber diaphragm suitable for moderate pressures.

(4.) *Self-closing Screw Taps.*—These taps will be found very useful for certain purposes, as they are not subject to the drawbacks incident to the last class of taps. Fig. 130 shows a tap constructed on the screw-down principle, and so contrived as to allow of the passage of only a certain quantity of water each time the valve is opened by the screw.

FIG. 130.



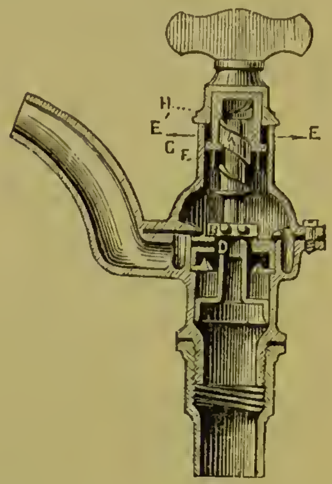

It is known as "the screw-down loose-valve tap" of Tylor and Sons. It is designed to prevent waste, if the tap is left with the water running. This is effected by the following arrangement:—The piston C is fitted with a washer valve H at bottom, and moves up and down in an adjustable socket EE. This socket is raised or depressed by the handle F. When the handle is turned it raises the socket which lifts with it the valve and opens the passage for the water through the tap.

A sufficient quantity of water having been drawn the handle is screwed down, which depresses the socket which takes down with it the valve on to the seating D. Should the handle not be screwed down and the tap left running, the piston valve descends on to the seating partly by its gravity but principally by the pressure of the water passing through the tap. This tap is declared to be equally suitable for outside as well as inside use.

Fig. 131 shows on a small scale the self-closing screw tap of Messrs. Wallace and Connell, of Glasgow. Like the tap just

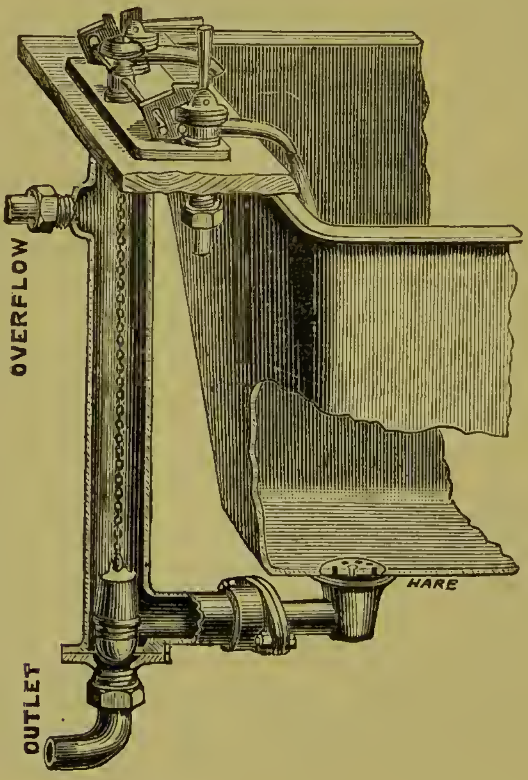
described a pailful or a pint only may be drawn, though the valve will close when a regulated quantity has passed through it.

FIG. 131.




XC.—BATH VALVES AND COCKS.—Numerous are the varieties of both bath valves and cocks now before the public; though it is generally acknowledged that the former are superior to the latter in that they involve less trouble to open and shut, especially when they are not in constant use.

FIG. 132.

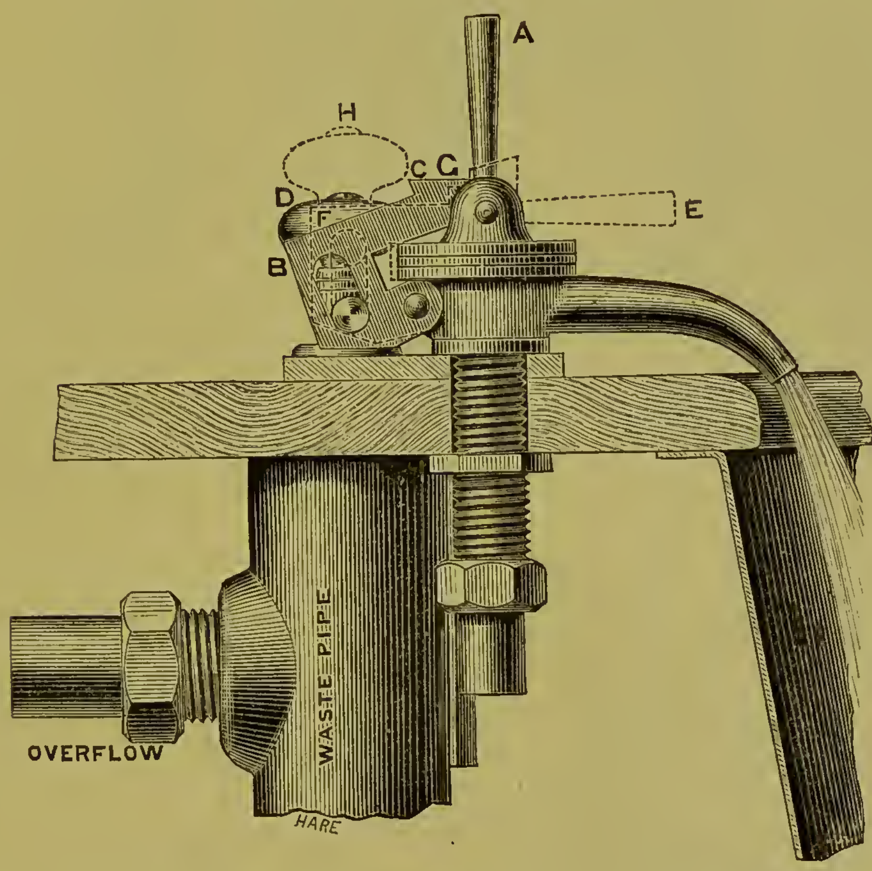


When plug-cocks are used, they have a ground—in plug with packing of ordinary packing cotton or other material, and a metal gland adjusted by two binding screws.

The " screw-down," the " diaphragm " and the " quarter turn round way," valves are those most frequently adopted for bath fittings. There are numerous sorts which are easy both to open and shut; the last description of valve possessing the extra advantage of coming into action at the quarter turn of the circle.

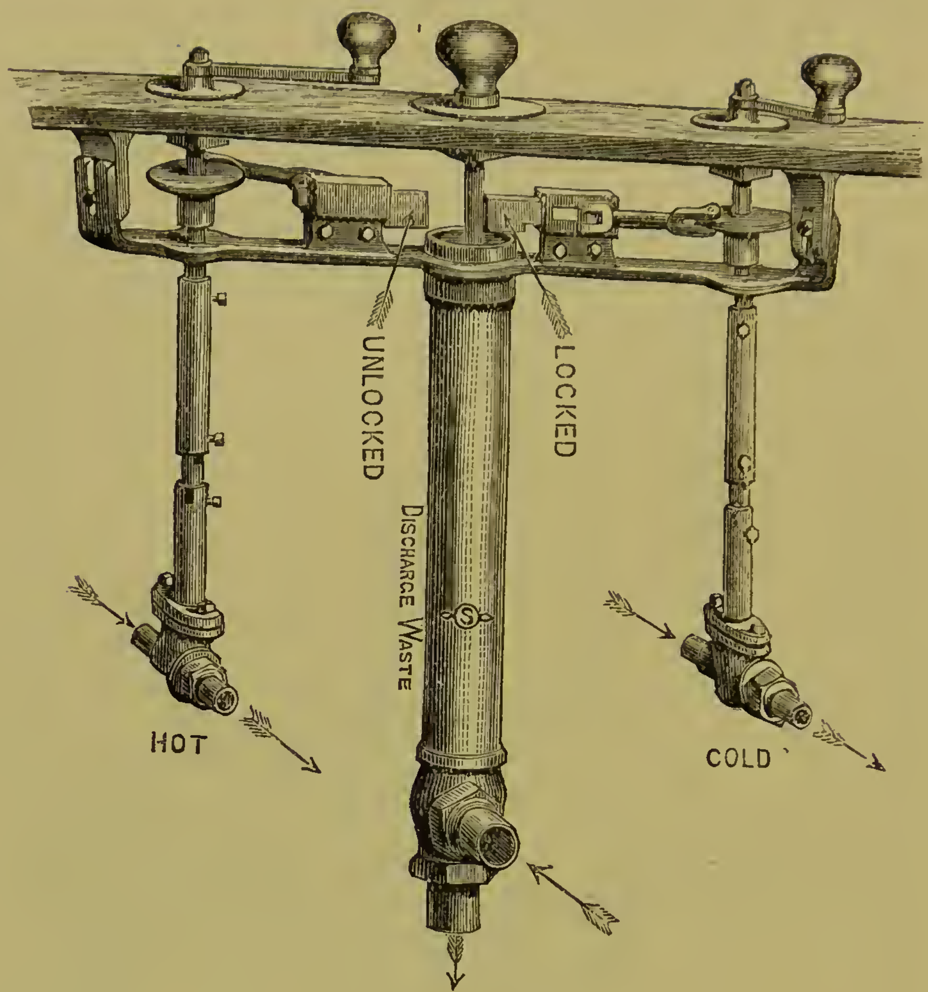
*Locking Apparatus.*—Locking apparatus for the prevention of waste in connection with the supply and waste valves is a very useful addition in all cases. Figs. 132, 133, and 134

FIG. 133.




illustrate two methods by which this object is obtained. Fig. 132 shows Doulton's improved locking apparatus as it is attached to a bath; whilst Fig. 133 shows an enlarged side elevation of the same locking gear with the supplies open and the waste locked, and in dotted lines with the waste open, and the supplies locked. Fig. 134 represents another somewhat similar invention by Messrs. Stidder and Co., of Southwark Bridge Road. It will be seen that in either invention it is impossible that the supply pipes and waste should be open at the same time.

FIG. 134.

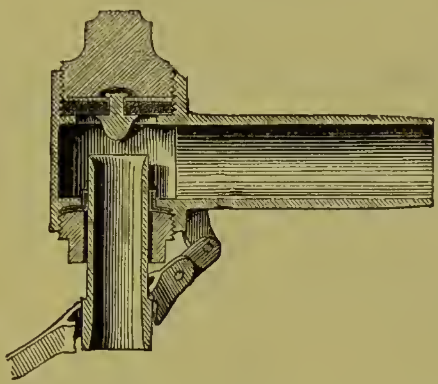



XCI.—BALL VALVES.—Ball valves though they are generally the only means provided for regulating the supply of water to the cisterns or tanks of a dwelling, are as a rule but little understood, and the waste which frequently takes place will be found to arise as much from their defective condition, which the occupier does not fully appreciate, as from any other cause. Ball valves are commonly used in connection with the general service and water-closet cisterns. Where the pressure is great, the water as it enters the cistern is necessarily much agitated, and many valves are, from their construction, subject to a great amount of wear and tear from this cause. Great care should therefore be taken to select those only which limit this wear and tear to a minimum. In testing the valves themselves, not only is it necessary that they should be sufficiently strong to withstand a maximum pressure when closed, but the lever or rod should be of such a character as to act with the fall or rise of the water in the cistern independently of any force which the water in the pipe may exercise upon the

valve. The number of valves and their characteristics are legion, and it would be indeed invidious to offer any selection beyond such specimens as will convey the ruling objects aimed at by different makers, all of whom declare that the water companies will sanction their use.

Fig. 135 represents the tube ball valve, made by Guest and Chrimes. The action of this kind of valve is very simple, the hollow vertical tube shown is connected with the ball rod

FIG. 135.



or lever, and rises or falls with the motion of the latter. When the ball rod is down as in the figure there is a space above the top of the tube. Through this space the water passes into and down the tube into the cistern. When the ball rod is up, the tube is pressed against an india rubber or other seating, and the passage of water down the tube is prevented.

FIG. 136.

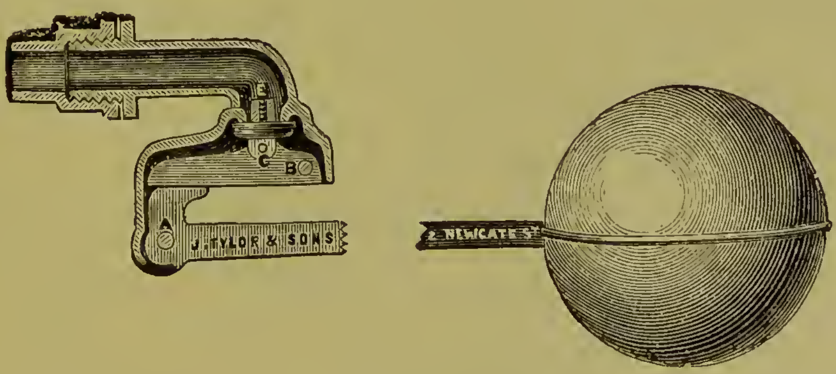



Figure 136 shows a lever ball valve manufactured by Messrs. Tylor and Sons—the chief feature of which is that the ball rod is not attached to the valve, and only acts upon it when it has been raised to a certain height. In this apparatus the power exerted by the flow of water in the pipe behind the valve is withstood by the working parts of the valve immediately above, and in a line with

the pin A, and not by the rod itself, which can only be raised or depressed by the rise or fall of the water in which it floats. The valve possesses the advantage of confining to the ball rod itself the jerking motion which is often given by the entry of the water, and its agitation in the cistern.

FIG. 137.

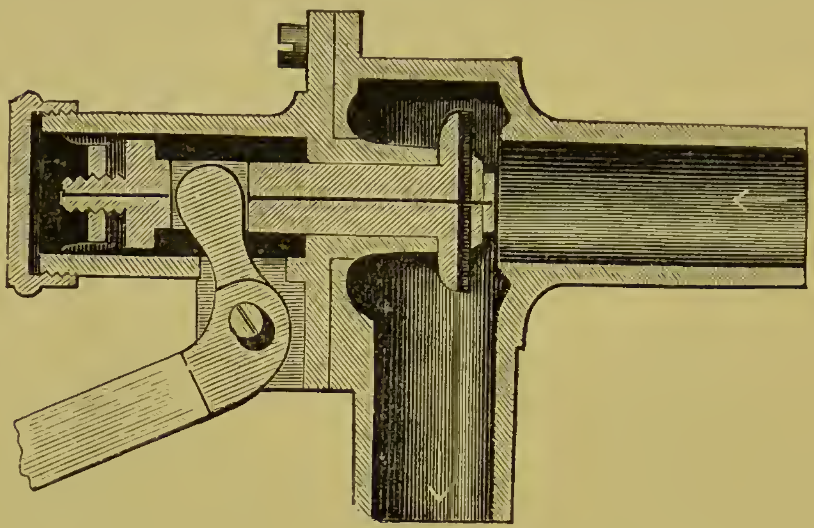


Fig. 137 shows a valve, which, unlike the previous examples, works in a horizontal direction. It is that known as the equilibrium ball valve of Underhay. The waterway of this valve continues clear until the cistern has become nearly full, a great consideration when the water supply is intermittent.

Fig. 138 represents Tylor's patent high pressure horizontal valve, which has now been tried for some years with satisfactory results in connection with the New River Water Company's supply. This valve also allows of the running of a full stream of water through it until the cistern is nearly filled.

FIG. 138.

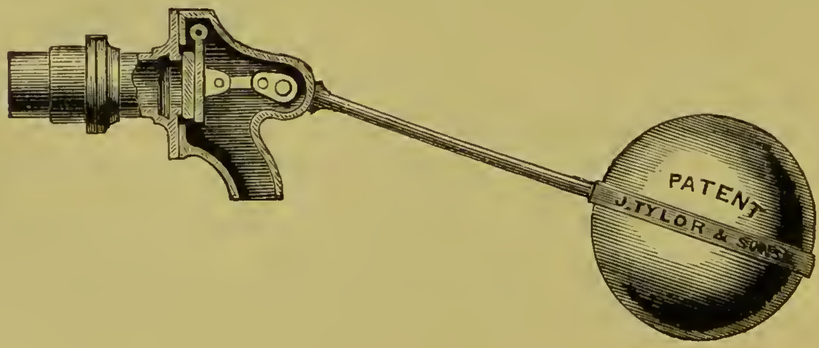
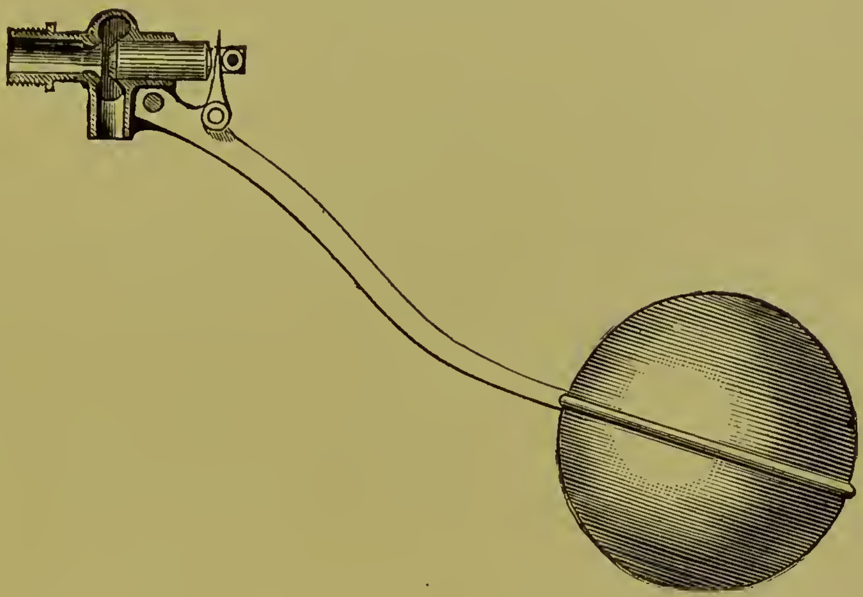


Fig. 139 represents the wedge ball valve sold by Messrs. Flood and Co., of Blackfriars.

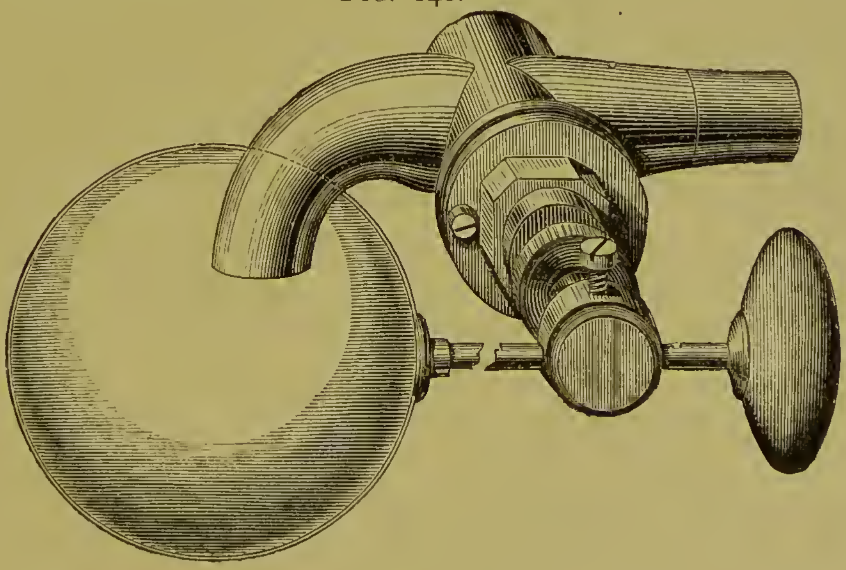
FIG. 139.



This valve is new in principle and ingenious. The valve being opened by the pressure of the water and closed by a wedge connected with the ball lever, and inserted between a plunger (the end of which forms the valve) and a roller fitting on to a pin fixed in the valve box. The inventors say it will work under both high and low pressure—that it can be equally well used with both hot and cold water, and that its parts are certain in their action. It is declared to be the cheapest high pressure ball valve in the market.

There is also, besides many others, the ball valve which is made on the " loose valve " principle. Fig. 140 shows the exterior

FIG. 140.



of one of these valves, made by Messrs. Guest and Chrimes, of Rotherham. A loose valve, the face of which is covered by a leather washer, is compressed on a prepared metallic seat by means of a screw, so threaded that the valve may be opened or shut with a very small fall or rise of water in the cistern.

In concluding this chapter on the distribution of water throughout the dwelling, it is hardly necessary to repeat more precisely than has already been done that, with respect to valves, cocks, and taps, the endeavour has been, as their kinds are very numerous, to direct attention into the right channel for personal examination, rather than to express decided opinions, which special or local circumstances may render inapplicable. Among the best prepared catalogues of distributing appliances will be found those of Messrs. Tylor, Bolding, Emanuel, and Doulton, of London; Messrs. Guest and Chrimes, of Rotherham; Messrs. Sutcliffe, of Halifax; though there are probably many others from which equally valuable information may be obtained.

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